International Journal of Sports Science & Coaching

The influence of calculation method and relative strength on the load-velocity relationship in bench press exercise

Journal:	*International Journal of Sports Science & Coaching*
Manuscript ID	SPO-21-0104.R1
Manuscript Type:	Original Research Article
Date Submitted by the Author:	28-Jun-2021
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Keywords:	Load-velocity profile, free-weight, velocity-based training, linear position transducer, handball
Abstract:	Purpose: The objective of this study was: (1) to compare the effect of the calculation method using average (Avalue), and best value (Bvalue) of MPV on the LVprofile during the barbell bench press exercise in elite handball players. In addition, (2) to analyze and compare the relationship between the individual coefficient of variation (CVind) of an incremental load protocol in the bench press exercise with relative strength (Frel) in professional handball players. Methods: Nine-teen elite international handball players (age 18 [☐1] y; body mass 93 [☐14] kg; height 191 [☐6] cm) performed an incremental test during the barbell bench press exercise. General and individual LVprofile, Frel, and CVind were modelled through mean propulsive velocity and two calculation models (Avalue, vs Bvalue). Results: There were significant differences (p<0.05) between both conditions (Bvalue vs. Avalue). There was an inverse relationship between the Frel and the CVind (r = -0.66, p < 0.001). When CVind was >10% significant differences were found between the two calculations method (Avalue, vs Bvalue). However, no significant differences were found between Avalue, vs Bvalue when the CVind was <10%. Conclusions: The calculation method used to assess the barbell bench press LVprofile impacts the nature of the relationship. Regardless CVind values, Avalue is a good choice to determine the LVprofile when the CVind is >10%, if the CVind is <10%, Bvalue will be the better option to determine the LVprofile

The influence of calculation method and relative strength on the load-velocity relationship in bench press exercise

ABSTRACT

Purpose: The objective of this study was: (1) to compare the effect of the calculation method using average (Avalue), and best value (Bvalue) of Mean Propulsive Velocity (MPV) on the Load Velocity Profile ($LV_{profile}$) during the barbell bench press exercise in elite handball players. In addition, (2) to analyze the relationship between the individual coefficient of variation (CV_{ind}) of an incremental load protocol in the bench press exercise with relative strength (F_{rel}) in professional handball players.

Methods: Nineteen elite international handball players (age 18 [±1] y; body mass 93 [±14] kg; height 191 [±6] cm) performed an incremental test during the barbell bench press exercise. General and individual $LV_{profile}$, $F_{rel,}$ and CV_{ind} were modelled through MPV and two calculation models (Avalue, vs Bvalue).

Results: There were significant differences ($p<0.05$) between both conditions (Bvalue vs. Avalue). There was an inverse relationship between the F_{rel} and the CV_{ind} ($r = -0.66$, $p < 0.001$). When CV_{ind} was >10% significant differences were found between the two calculations method (Avalue, vs Bvalue). However, no significant differences were found between Avalue, vs Bvalue when the CV_{ind} was <10%.

Conclusions: The calculation method used to assess the barbell bench press $LV_{profile}$ impacts the nature of the relationship. Regardless CV_{ind} values, Avalue is a good choice to determine the $LV_{profile}$ when the CV_{ind} is >10%, if the CV_{ind} is <10%, Bvalue will be the better option to determine the $LV_{profile}$

Keywords: Load-velocity profile, free-weight, velocity-based training, linear position transducer, handball.

INTRODUCTION

The bench press is a classic exercise which is frequently used to assess maximum dynamic force (MDF) or the absolute one repetition maximum (1RM) [1]. In addition, this exercise is also commonly used to assess the optimal load for maximal power production [2], numbers of sets and repetitions at a given power load [3] and/or to test relative strength (F_{rel}; the 1RM divided by body weight) [4]. However, recent technological advances (i.e., linear position transducers, smartphone apps, wearables) have emerged that allow for the quantification of velocity, force and power during each repetition [5]. These technologies allow for the determination of the Load-Velocity profile ($LV_{profile}$) for resistance training exercises such as the bench press or squat [6, 7]. Such novel technologies are also used to indirectly assess the bench press 1RM [8] to monitor changes in the LVprofile after an intervention program and to determine the athlete's current performance capacity [7]. Traditionally, the $LV_{profile}$ is obtained by quantifying the velocity (i.e., mean velocity [MV] or mean propulsive velocity [M_{PV}]) of movement across a series of increasing loads (i.e., % RM or absolute loads [kg]). The most common method for determining the $LV_{profile}$ uses an incremental protocol that requires 5-7 increasing loads in order to establish an individualized relationship [8]. Recently, it has been suggested that it is possible to obtain the $LV_{profile}$ with as few as 2 increasing loads [7, 9, 10]. Additionally, when determining the $LV_{profile}$ for resistance exercises, such as the bench press, 2-4 repetitions (although the number of repetitions usually decrease in relation to the load lifted) are performed at each incremental load protocol used to create the profile [7].

Another important methodological consideration is determining what velocity is better to representing the athlete's performance (i.e., the best value [Bvalue], defined as the highest velocity value within a set of repetitions vs. the average value [Avalue], defined as the mean velocity value within a set of repetitions). Recently, Claudino, Cronin [11] performed a meta-analysis to determine which value best represents the neuromuscular function in the countermovement jump (CMJ) exercise. After analyzing a total of 151 articles and more than 530 effect sizes (ES), the average CMJ height of a set was determined to be more sensitive than the highest CMJ height value for detecting fatigue and performance supercompensation. Al Haddad, Simpson [12] conducted a similar study with young football players where they analyzed CMJ performance and sprint ability (10-m) using the mean of 2 repetitions or the best value of each test. Similar results were observed between both data treatment methodologies. Hence, these results suggested that both approaches may be valid for monitoring changes in functional performance tests. However, an essential goal when monitoring individual “real” performance changes is to identify the most valid/representative procedure (e.g., Bvalue vs. Avalue).

Throughout the scientific literature that has examined the $LV_{profile}$ in the bench press exercise, there is no consensus on the best method for determining this relationship with some studies that have used the average velocity across several repetitions [5,13] and other studies that have used the repetition with the highest velocity [1, 7, 14, 15]. Hence, when examining these methods, it is possible that selecting the Bvalue as a performance variable may not always be representative of the athlete's performance status. For example, two athletes who lift a load of 20 kg: athlete 1, rep 1 (1.30 m/s) rep 2, (1.25 m/s) rep 3 (1.22 m/s) and rep 4 (1.20 m/s) [Bvalue = 1.30 m/s, Avalue = 1.24 m/s]; and, athlete 2: rep 1 (1.28 m/s) rep 2 (1.28 m/s), rep 3 (1.27 m/s) and rep 4 / 1.27 m/s) [Bvalue = 1.28 m/s Avalue = 1.27 m/s]. By selecting the Bvalue as the final performance variable, athlete 1 would have a higher performance than athlete 2. However, if we take the Avalue, athlete 2 exceeds athlete 1 by 0.03 m/s. On the other hand, by performing fewer and/or more repetitions during the incremental load protocol we may not obtain a representative performance value or trigger an excess of neuromuscular fatigue, respectively. For this reason, depending on the evaluation procedure used, it is necessary to define an optimal analysis strategy in order to avoid or reduce measurement errors and, consequently, erroneous results interpretation.

Therefore, the main purpose of this study was to compare the difference in the $LV_{profile}$ between methods that either use Avalue and Bvalue to determine the impact on the athlete profile in the barbell bench press exercise. In addition, a secondary objective of the present study was to analyze and compare the relationship between the individual coefficient of variation (CV_{ind}) of an incremental load protocol in the bench press exercise with relative force (F_{rel}) in professional handball players. Our hypotheses were that the method of analysis influences the $LV_{profile}$ and players with a better F_{rel} will be those players with les CV_{ind}.

METHOD

Subjects

Nine-teen professional handball players (age: 18 [±1] y; body mass: 93 [±14] kg; and, height: 191 [±6] cm) voluntarily participated in this study. All subjects were elite international players of the Spanish Handball National Team (U21). All participants had more than 3 years of experience in the barbell bench press exercise. The study procedures were in accordance with the principles of the Declaration of Helsinki and were approved by the Institutional Review Board of the University of Valencia which granted its approval to carry out the study within its facilities, IRB code: H1421157445503.

Design

A non-experimental descriptive-correlational study was performed to analyze the influence of calculation method over velocity execution on an incremental load protocol in the bench press exercise. Independent variables were a) calculation method (i.e., Bvalue vs. Avalue) and b) protocol intensity (i.e., 20 to 80 kg, with increments of 10 kg). Dependents variables were M_{PV} (m/s), CV_{ind} (%) during the incremental load protocol and F_{rel} (kg*kg).

Methodology

Incremental Load Strength Testing. Participants performed a standardized mobility and dynamic warm-up consisting of 5 minutes of low-resistance cycling on an ergometer (Excite Unity 3.0, Technogym S.p.A, Cesena, Italia) and 2 minutes of shoulder, elbow and wrist mobility exercises, followed by 2 bench-press warm-up sets. The first warm-up set consisted of ten repetitions at 30% of estimated 1RM and the second warm-up set consisted of six repetitions at 50% of estimated 1RM, allowing 1 min of rest between sets. Then, 5 minutes of rest was allocated before initiating the free weight bench press test. The bench press test was carried out using an Olympic bar (20 kg) and 5 and 10 kg discs (Salter SL, Barcelona, Spain). The incremental load protocol [16] began with a 20 kg load (corresponding to the weight of the bar). There were constant increases of 10 kg between each of the loads until 80 kg. When the execution velocity was greater than 0.70 m/s, 3-minute breaks were employed. When the bar velocity was <0.70 m/s the set was stopped and finished, and a 5-minute break was applied. During the eccentric phase, the barbell was lowered until contacting with the chest, and the concentric action ended when the elbows reached full extension. No pause between the eccentric and concentric phase was required. Participants were instructed to apply a maximal velocity concentric action during the initial momentum and throughout each repetition. Verbal encouragement was provided during the concentric phase in order to ensure maximal effort was achieved. Two trained spotters were present on each side of the bar to ensure safety. All trials were performed with a self-selected grip and replicated in each set. During the testing period no information about velocity execution was provide to the subjects. The 1RM was estimated trough the individual $LV_{profile}$.

All data was collected with the use of a velocity transducer (T-Force Dynamic Measurement System, Ergotech, Murcia, Spain). This system consists of a velocity transducer that is connected to a personal computer by means of a 14-bit resolution analog to digital data acquisition card and custom software. The instantaneous vertical velocity was sampled directly by the device at a frequency of 1000 Hz. The velocity of the propulsive phase was defined as the part of the concentric phase during which the measured acceleration (a) is greater than the acceleration due to gravity (i.e., to ≥ -9.81 m/s^{-2}) (5). The number of repetitions performed at each set, in relation to the load lifted, were: 20 kg–30 kg (4 rep), 40 kg–70 kg (3 rep) and 80 kg (2 rep). All repetitions were exported to an excel sheet for the final calculations (i.e., Avalue vs. Bvalue). After that, the individual $LV_{profile}$ for each participant was determined and the velocities attained at each % 1RM (increments of 10% from 20% 1RM to 90% 1RM) were represented [17].

Statistical Analysis

All results were expressed as mean (M) and standard deviation (SD). All variables met the normality assumption (e.g., Shapiro-Wilks). To compare the influence of the type of calculation method (i.e., Bvalue vs. Avalue) over the $LV_{profile}$ slopes a t-test of dependent samples was performed. The Effect Size (ES) was calculated using Hedges' g and the associated 95% confident interval ($CI_{95\%}$) was used to assess the magnitude of mean differences between conditions. The individual coefficient of variation (CV_{ind}) was calculated as mean value divided by SD multiply by 100 at each load and then all CV_{ind} values were averaged. After, this value was averaged in relation to all the loads made in the incremental protocol. On the other hand, Pearson's correlation coefficient was used to analyze the relationships between F_{rel} and CV_{ind}. Finally, the sample was divided between those athletes with less than 10% of CV_{ind} or a higher value of 10% of CV_{ind}. A factorial analysis of variance (ANOVA 2 x 2) 2 [Avalue and Bvalue slopes] x [CV_{ind} <10 or >10%] was performed. Significant level was established as $p < 0.05$. All analyses were performed using statistical analysis software (SPSS Inc, V.24, Chicago, Illinois, USA).

RESULTS

Table 1 summarizes the descriptive statistics, mean [SD] of percentages of 1RM, M_{PV} in relation to the Bvalue or Avalue of each set at each load lifted and the difference in the M_{PV} between Bvalue minus Avalue.

***** Insert Table 1 here *****

The slopes of the $LV_{profile}$ were calculated for both conditions (Bvalue vs. Avalue). There were statistically significant differences ($t_{(18)} = 2.52$, $p = 0.021$). The Bvalue calculation resulted in a greater slope when compared the Avalue (ES = 0.36, $CI_{95\%}$ (0.60 – 0.12) , see Figure 1a) calculation method. Figure 1b shows ES for each intensity in $LV_{profile}$.

***** Insert Figure 1 here*****

On the other hand, the Pearson correlation coefficient (R^2= 0.44; p= 0.001) between F_{rel} vs. CV_{ind} are reported in Figure 3.

*****Insert Figure 2 here*****

When the slopes of $LV_{profile}$ where comparted in relation to calculation method (i.e., Avalue vs. Bvalue) and CV_{ind} (i.e., <10% vs. >10%) statistically significant differences in "*calculation method*" ($F_{[1,\ 17]}$= 12.82; p = 0.002; η^2_p= 0.43) and "*calculation method x CV*" variables ($F_{[1,\ 17]}$= 7.69; p = 0.013; η^2_p= 0.31) were determined. When CV_{ind} was higher than 10% statistically significant differences between Avalue vs. Bvalue slopes (mean differences [MD]= -0.0015; p = 0.0014) were determined. However, no significant differences were found between $LV_{profile}$ slopes when either the Avalue or Bvalue is used when the CV_{ind} was less than 10% (MD= 0.0002; p= 0.515).

****Insert Figure 3 here****

DISCUSSION

The main objective of this study was to compare the effect of the calculation method (i.e., Avalue vs. Bvalue of M_{PV}) on the $LV_{profile}$ during the free-weight bench press exercise in elite handball players. The relative strength of each player was correlated with the CV_{ind} obtained from the incremental load protocol in the bench press exercise. To the authors knowledge, this is the first study that compares the influence of a calculation method on the $LV_{profile}$ in a bench press when an incremental load protocol is used with elite handball players. Based upon our results the calculation method (i.e., Avalue vs. Bvalue) impacted the $LV_{profile}$. CV < 10% implies higher levels of relative strength. Also, the calculation method affects the LV profile only when the individual CV is higher than 10%.

Several studies have analyzed the reliability of $LV_{profile}$ using exercises such as the bench press [18], squat [1,6], sled-push [19] and deadlift [20]. However, none of these studies have investigated the most appropriate value that represents the athlete's performance. Recently, a study performed by García-Ramos, Pestaña-Melero [18] analyzed the between-session reliability of different velocity variables (i.e., MV, M_{PV} or peak velocity) typically used to create the $LV_{profile}$ based upon an incrementally load free-weight bench press protocol. While this study was performed using a Smith Machine, the MV was determined to be the most stable variable when monitoring a relative 1RM load. However, the final performance variables were calculated using the Bvalue obtained from each set contained in the incremental load protocol. As only the Bvalue was examined, it is not possible to directly establish the differences between Bvalue vs. Avalue in the study conducted by García-Ramos, Pestaña-Melero [18]. To address this topic, the present study examine both calculation methods in order to determine the differences between the Avalue and the Bvalue across a range of loads (from 20 to 90% 1RM) during a bench press protocol. Indeed, based upon our data it appears that the method of calculation directly impacts the M_{PV} in the $LV_{profile}$ (Figure 1A). Specifically, the $LV_{profile}$ slope was significantly different between Avalue vs. Bvalue. In addition, when ES was calculated, moderate to large differences were found between both methods (see Figure 1B).

Similarly, Claudino, Cronin [11] elucidated which value (i.e., Bvalue vs. Avalue) was more sensitive when CMJ height is used to determine a practical solution for tracking neuromuscular fatigue. Albeit the vast majority of studies have analyzed the highest CMJ height, the average jump height across a series of CMJs was determined to be more sensitive at detecting neuromuscular fatigue or indicating the occurrence of supercompensation. In the present study, it was observed that depending on the calculation method selected (i.e., Avalue vs. Bvalue), statistically significant differences were obtained in the M_{PV} in all loads assessed (see Figure 1A). Ultimately, the calculation method directly impacted the $LV_{profile}$ (see Figure 3). Thus, CV_{ind} seems to be a key variable to determine the $LV_{profile}$. As can be observe in Figure 3B, an athlete with a low CV_{ind} (<10%) achieves a similar $LV_{profile}$ regardless of which calculation method (Avalue or Bvalue) is used to determine the profile. In contrast, as shown in figure 3A, differences in the $LV_{profile}$ were observed in those athletes with high CV_{ind} (>10%). Our results are consistent with those reported by Cormack, Newton [21], who concluded that a CV_{ind}<10% should be considered prior to determine the $LV_{profile}$. Hence, a low CV_{ind} and a high F_{rel} are often related to a better training background and/or a greater familiarity with the loads employed during assessment [22].

In addition, our findings support the idea that it is important to consider the CV_{ind} and that it is critical that the specific calculation method (Avalue or Bvalue) employed when creating a $LV_{profile}$ is reported. As shown in Figure 3, depending upon the calculation method used an athlete can display different $LV_{profile}$ during a given exercise. Secondly, athletes who present a high CV_{ind} tended to have lower relative strength when compared to athletes who demonstrated a low CV_{ind}. In this sense, it seems logical that those athletes with a lower CV_{ind} showed better F_{rel} values. We acknowledge that there are some limitations to the current study. Firstly, a lack of a second assessment day to compare absolute and partial reliability of the methods used. In this regard, when dealing with professional athletes it is difficult to adapt training and evaluations to the competitive calendar. Secondly, our results only can be related to the bench press exercise. Future research is required to understand if these findings can be replicated with different resistance training exercises such as the back squat or row.

CONCLUSIONS

The calculation method used to assess the $LV_{profile}$ for the free-weight bench press exercise impact only in subjects with CV_{ind} > 10%. The Bvalue of velocity resulted in steeper $LV_{profile}$ slopes compared to employment of the Avalue. On the other hand, a significant relationship was determined between the CV_{ind} and F_{rel} suggesting that athletes with a higher F_{rel} tend to have a lower CV_{ind} during an incremental load protocol in the bench press exercise. Finally, our results suggest that when calculating the $LV_{profile}$ of an athlete it would be advisable to calculate, first, the CV_{ind}. If the CV is <10%, the calculation method would be indifferent, but if the CV is >10%, one should proceed with caution and take into account the possibility of establishing the $LV_{profile}$ by the Avalue instead of the Bvalue.

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International Journal of Sports Science & Coaching

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Head title: L-V profile calculation in bench press

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Acknowledgements

None

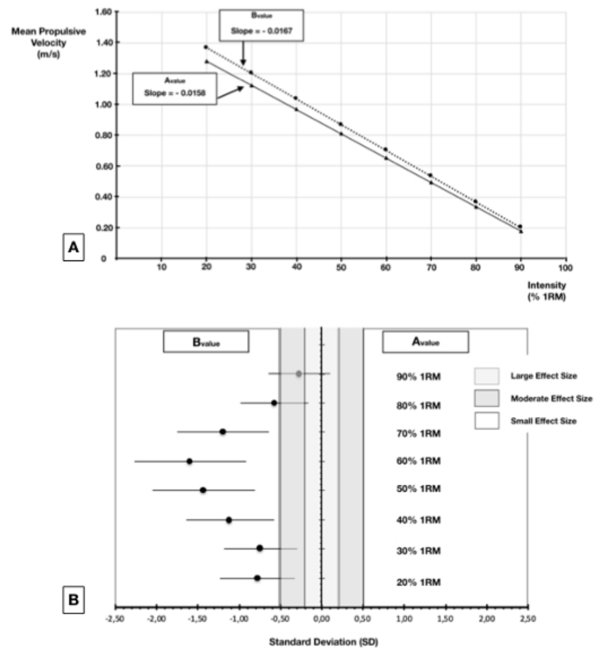

Figure 1. (A) Representation of the Load-Velocity relationship (LVrelationship) in both calculation methods (best value [Bvalue] vs. average value [Avalue]) in bench press exercise. (B) Effect size between de differences in best value [Bvalue] vs. average value [Avalue] in Load-Velocity relationship.

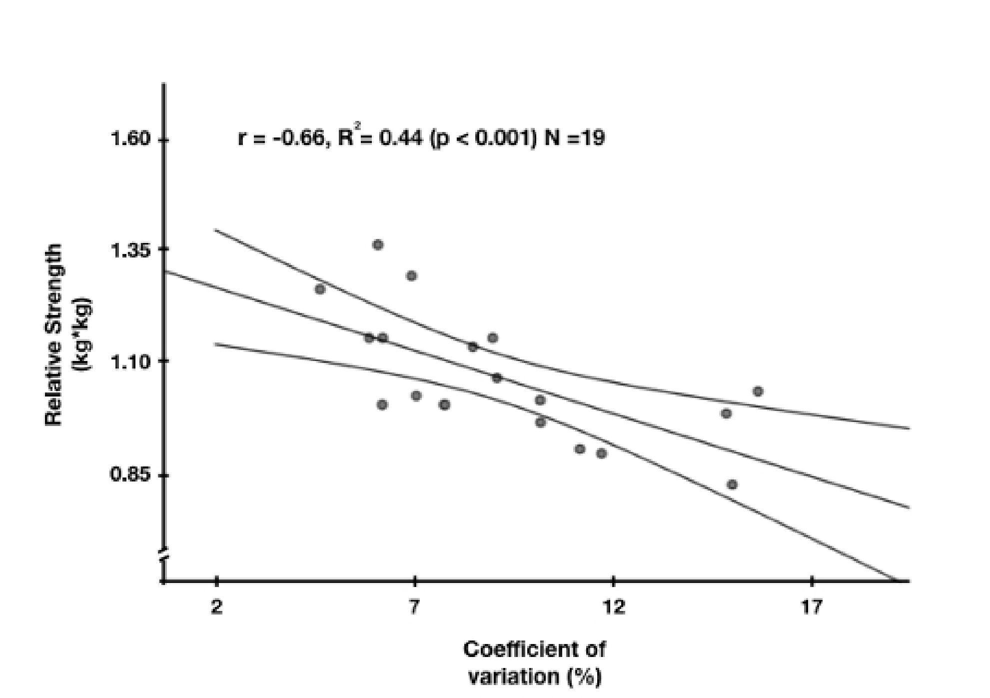

Figure 2. Relationship between individual coefficient of variation (%) of the protocol vs. relative strength (kg*kg). Lines represent 95% Interval Confidence of the mean.

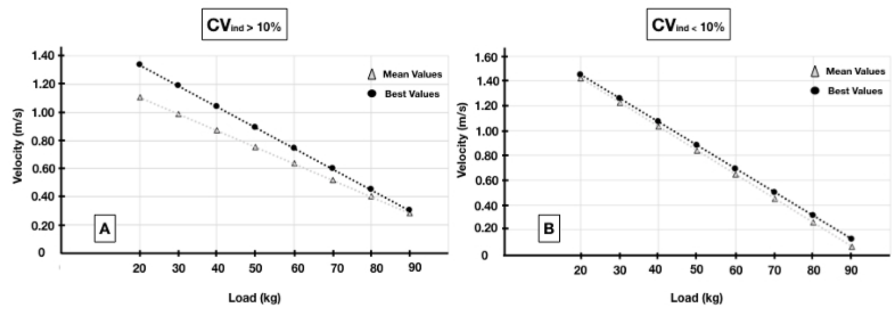

Figure 3. A: Load-Velocity profile (LVprofile) for the same athlete but with a different calculation method (best values [circles] and average values [triangles]) with a high individual coefficient of variation (CVind). B: LVprofile for the same athlete but with a different calculation method (best values [circles] and average values [triangles]) with a low CVind.

Load (% 1RM)	20	30	40	50	60	70	80	90
A_{value} (m/s)	1.28 (0.11)	1.13 (0.09)	0.97 (0.06)	0.81 (0.04)	0.65 (0.03)	0.49 (0.04)	0.34 (0.05)	0.18 (0.07)
B_{value} (m/s)	1.37 (0.08)	1.20 (0.07)	1.04 (0.05)	0.87 (0.04)	0.70 (0.04)	0.54 (0.05)	0.37 (0.06)	0.20 (0.07)
Differences ($B_{value} - A_{value}$) (m/s)	0.09 (0.06)	0.08 (0.05)	0.07 (0.04)	0.06 (0.03)	0.05 (0.02)	0.04 (0.03)	0.03 (0.04)	0.02 (0.05)