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Review paper

BARBELL VELOCITY IN STRENGTH TRAINING – A LITERATURE REVIEW

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Abstract

Introduction. Barbell velocity is widely used in strength training and Olympic weightlifting as an indicator of movement quality, training intensity and neuromuscular performance. In recent years, velocity-based training (VBT) has become increasingly popular due to its applications in load prescription, fatigue monitoring and autoregulation. The aim of this narrative review is to summarize the current knowledge (2015–2025) on the use of barbell velocity in strength exercises (squat, deadlift, bench press) and Olympic lifts (snatch, clean and jerk) and their derivatives. ***Material and Methods.*** Relevant literature published between 2015 and 2025 was identified through searches of PubMed, ScienceDirect, Google Scholar and EBSCO databases, using keywords related to barbell velocity, load-velocity relationships and velocity-based training. Both original studies and review articles were included to provide a broad synthesis of evidence. ***Results.*** Across studies, peak barbell velocity (PBV), mean barbell velocity (MBV), and mean propulsive velocity (MPV) show strong and consistent relationships with Percentage of One-Repetition Maximum (%1RM), supporting their use for estimating maximal strength and regulating training intensity. Olympic lifts exhibit higher velocity values due to their ballistic nature, while classical strength exercises show stable load-velocity profiles. Measurement tools differ in precision, influencing the comparability of results. ***Conclusions.*** Barbell velocity is a practical and valuable indicator in strength and Olympic weightlifting training. It enables accurate load prescription, monitoring of readiness, and assessment of technical execution. However, the lack of methodological standardization across studies remains a limitation. Further research is needed to unify measurement procedures and validate emerging technologies.

Keywords: barbell velocity, velocity-based training, strength training, weightlifting, PBV, MBV, power

Introduction

The development of modern sport necessitates the search for new methods of evaluating and optimizing training loads. One of the key biomechanical parameters used for this purpose is barbell velocity, which enables the assessment of movement quality and resistance training intensity [1]. The rate of barbell displacement reflects the neuromuscular system's ability to generate force as well as the stability of technical execution [2, 3].

In recent years, the concept of velocity-based training (VBT) has gained increasing reference. Within this framework, peak barbell velocity (PBV), mean barbell velocity during the concentric phase (MBV), and mean propulsive velocity (MPV) are applied to autoregulate training loads, monitor fatigue, and predict maximal strength without the need for maximal testing [4, 5]. Traditionally, VBT has been applied to exercises with relatively simple movement patterns, such as squats and bench press, where load-velocity relationships are easily captured [1, 6]. However, growing scientific interest has also extended to more complex and ballistic exercises, particularly Olympic lifts [7, 8].

The snatch and the clean and jerk, which require high levels of coordination, speed, and stabilization, allow for velocity analysis not only in the final phases of movement but also across specific technical segments – such as the first pull, the second pull, or the transition phase under the barbell [9]. Velocity analysis thus has both scientific and practical dimensions. On the one hand, it provides insights into the interactions between external load, kinematic parameters, and adaptive outcomes [10, 11]. On the other hand, it offers coaches tools for more precise planning of periodization, fatigue management, and evaluation of training effectiveness [12, 13].

Although several studies have examined barbell velocity in strength exercises and Olympic lifts [14, 15], there is still a need for integrative work that brings these findings together. This article aims to address this gap by synthesizing recent findings (2015-2025) on PBV and MBV values in selected strength exercises, applications of VBT in strength and power training, and measurement tools used for barbell velocity assessment.

The objectives of this review article are to:

- present the current state of knowledge on peak barbell velocity (PBV) and mean barbell velocity (MBV) values in selected strength exercises, including the snatch and its derivatives, the clean and jerk and its derivatives, the squat, the deadlift, and the bench press;
- discuss the application of velocity-based training (VBT) methods in strength and power development among both elite athletes and recreational lifters;
- analyze the influence of external load (%1RM) on barbell dynamics across different exercises;
- identify the measurement variables and tools used in studies on barbell velocity.

Material and Methods

This article is a narrative review, designed to synthesize current knowledge on barbell velocity without applying the methodological restrictions of a systematic review. The aim of this approach is to provide a broad and integrative overview of research findings published between 2015 and 2025.

Literature Search Strategy

Relevant literature was identified through searches conducted in the following databases and platforms:
- PubMed,
- ScienceDirect,
- Google Scholar,
- EBSCO.

The following combinations of keywords were used: "barbell velocity," "velocity-based training," "1RM prediction," "peak barbell velocity," "mean barbell velocity," "Olympic lifts velocity," "power clean velocity," "snatch velocity," "strength training," "movement tempo," "VBT." Additionally, the bibliographies of selected studies were reviewed to identify further relevant references.

Inclusion of Evidence

To provide a comprehensive overview, this narrative review includes:
- original research studies,
- review articles,
- systematic reviews and meta-analyses.

Studies were considered when they addressed:
- barbell velocity indicators (PBV, MBV, MPV),
- load-velocity relationships,
- measurement tools (LPTs, IMUs, video-based applications),
- strength exercises (squat, deadlift, bench press),
- Olympic lifts and their derivatives.

The emphasis was placed on extracting key findings, typical velocity values, methodological considerations and practical implications.

Narrative Synthesis

Given the non-systematic nature of this review:
- no formal PRISMA protocol was applied,
- no risk-of-bias assessment was conducted,
- no quantitative pooling or meta-analytic procedures were performed.

Instead, studies were grouped narratively according to thematic areas such as: barbell velocity indicators, measurement tools, methodological standardization, and exercise-specific velocity characteristics.

Results

Barbell Velocity Indicators

Barbell velocity is a practical indicator of execution quality and the current state of the neuromuscular system. Research most frequently analyzes three parameters: peak barbell velocity (PBV), mean barbell velocity during the concentric phase (MBV), and mean propulsive velocity (MPV) [6, 16]. PBV more accurately reflects the characteristics of ballistic movements, in which maximal acceleration and the time to generate peak power are of primary importance [3, 7]. MBV is most commonly used in classical strength exercises, as it correlates consistently with %1RM and allows estimation of working loads without the need for maximal testing [1, 14]. MPV appears more sensitive than MBV to technical and fatigue-related changes, making it useful for monitoring power training and assessing the quality of successive repetitions within a set [16, 17].

In practice, the choice of velocity indicator should reflect the nature of the exercise: PBV and MPV are more frequently analyzed in Olympic lifts and their derivatives, while MBV is predominantly applied in squats, deadlifts, and bench press [15, 18]. Developing individualized load-velocity profiles and updating them throughout the training cycle improves the precision of load autoregulation [19, 20].

Measurement Tools

The choice of technology directly affects the obtained values, measurement reliability, and the feasibility of implementing monitoring in the training environment. Linear position transducers (LPTs) are the most commonly used tools in sports practice – they provide high agreement with laboratory systems and enable immediate feedback for the athlete [21, 22]. Inertial measurement units (IMUs) represent a mobile solution, sufficiently reliable for daily monitoring, although their precision depends on the algorithms applied and the method of sensor attachment to the barbell [4, 19]. Mobile applications based on video analysis are widely available and inexpensive. They perform well in exercises with a simple bar path, but their limitations include lower accuracy in ballistic movements and sensitivity to uncontrolled lighting conditions [23, 24]. Recent solutions incorporate everyday devices, such as smartwatches or AI-based systems, which are achieving increasingly higher levels of reliability [25, 26]. Comparative analyses have demonstrated that values obtained from commercial measurement devices may differ significantly depending on the exercise performed and the algorithm applied [27]. For example, García-Ramos et al. confirmed that the two-point method is a practical and reliable tool for estimating 1RM in the bench press based on velocity measured at two submaximal loads [28]. Conversely, van den Tillaar et al. showed that velocity and 1RM estimates are strongly influenced by the measurement technology used, highlighting the necessity of considering both the device type and the measurement procedure when interpreting data [29].

Standardization of Protocols

The consistency and comparability of research findings on barbell velocity largely depend on the unification of key elements of the experimental procedure. A standard warm-up typically includes several minutes of general activity followed by 2-4 preparatory sets performed with progressively increasing loads. In preparation for Olympic lifts, derivative exercises are often incorporated to activate specific movement patterns and enhance sport-specific mobility [8, 30]. Another critical aspect is the length of rest intervals between sets, which in most protocols ranges from 2 to 5 minutes when loads equal to or greater than 80% 1RM are used. An alternative approach involves regulating rest periods not on the basis of fixed time but according to the magnitude of velocity loss within a set. This strategy allows for more precise control of fatigue accumulation and better adjustment of exercise intensity to the athlete's current capacity [5, 12]. In this context, a systematic review and meta-analysis by Jukic et al. demonstrated that applying velocity loss thresholds in resistance training produces both short-term effects in terms of fatigue reduction and long-term adaptations that enhance strength and power development [31]. Similar conclusions were drawn by Chen et al., who emphasized that the implementation of velocity loss thresholds in resistance training can serve as an effective strategy for optimizing the development of lower-limb explosive capacity [32]. During the concentric phase, maximal intended velocity is recommended, while the eccentric phase should be performed in a controlled manner to improve measurement reliability [1, 17]. In Olympic lifts, trial segmentation and precise determination of the reference point for PBV – for instance, from barbell lift-off to the highest point of the trajectory – are essential [2, 9, 33]. The placement of the measuring device also significantly affects velocity values and the shape of the load-velocity profile. Comparisons of different registration methods in squats and bench press have shown that both the choice of technology and the measurement procedure play a crucial role in ensuring the reliability of results [34, 35].

Exercise Analysis

Each exercise – from the snatch and the clean, through the squat, to the deadlift and bench press – is characterized by distinct values of peak barbell velocity (PBV) and mean barbell velocity (MBV), resulting from the biomechanical specificity of the movement. The comparison of these parameters enables evaluation of exercise dynamics and highlights the importance of velocity-based training in monitoring strength and power adaptations (Fig. 1).

Snatch

The snatch is one of the most complex Olympic lifts, requiring high levels of speed, coordination, and technical precision. Studies indicate that at loads corresponding to 80-90% 1RM, PBV values typically range from 1.65 to 1.85 m/s, while MBV averages 1.20-1.40 m/s [3, 7]. Derivative variations, such as the hang power snatch or power snatch, display higher PBV values due to their shorter trajectory and the absence of a full squat under the bar [36].

In snatch derivatives, barbell velocity exceeds system velocity, highlighting the need to distinguish between these two parameters in kinematic analyses [37]. Typical values for these exercises are PBV 1.80-1.95 m/s and MBV 1.30-1.45 m/s at loads of 60-70% 1RM. Sandau and Granacher demonstrated that increasing load significantly alters acceleration-phase parameters in the snatch, underscoring the crucial role of the load-velocity relationship in evaluating performance quality [38].

For assistance exercises, such as the snatch pull performed at 100% 1RM, PBV values range from 1.40 to 1.65 m/s and MBV from 1.00 to 1.20 m/s [7, 30]. Analyses of barbell trajectories in international competitions revealed high repeatability of kinematic patterns among world-class athletes, confirming the

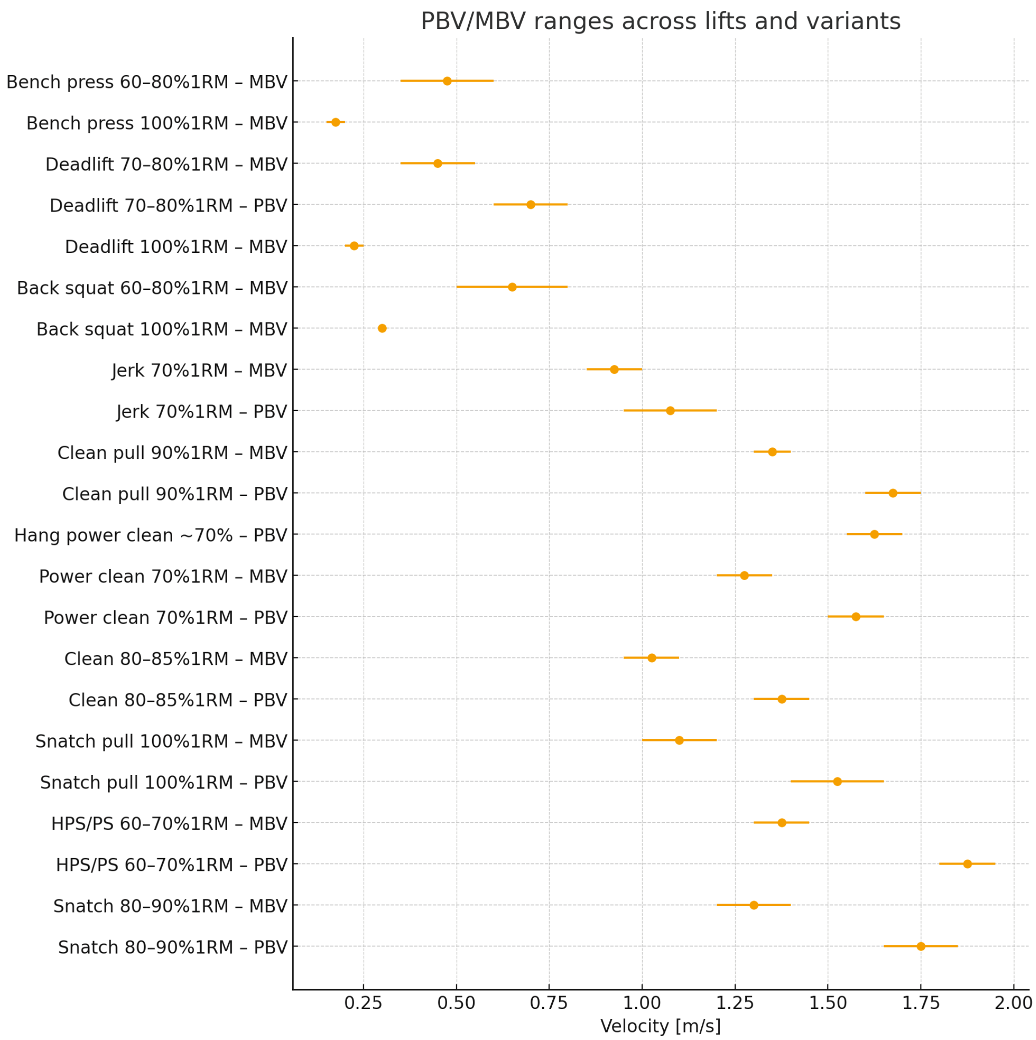

Fig. 1. Ranges of peak barbell velocity (PBV) and mean barbell velocity (MBV) in selected strength and Olympic weightlifting exercises (snatch, clean and jerk, squat, deadlift, bench press) at different %1RM values.

importance of velocity monitoring as an indicator of technical quality [8]. Sandau, Langen, and Nitzsche emphasized that examining barbell kinematic variability over time can provide valuable insights into technical stability among elite lifters [39].

Clean and Jerk

The clean and jerk, consisting of the clean and the overhead jerk, combines elements of maximal strength, speed, and stabilization. In the clean, PBV values at 80-85% 1RM typically reach 1.30-1.45 m/s, while MBV ranges from 0.95 to 1.10 m/s [2]. The power clean performed at approximately 70% 1RM shows PBV values of 1.50-1.65 m/s and MBV values of 1.20-1.35 m/s, supporting its use in maximal strength prediction [2]. The hang power clean demonstrates even higher PBV values (1.55-1.70 m/s), which was confirmed by Suchomel et al., who highlighted its effectiveness in assessing movement dynamics [9]. Conversely, the clean pull performed at 90% 1RM produces PBV values between 1.60 and 1.75 m/s and MBV values of 1.30-1.40 m/s [7]. Additionally, Takei et al. reported that different weightlifting derivatives selectively engage distinct regions of the force-velocity curve, explaining the variability in PBV and MBV observed across clean and pull variations [40]. Although direct analyses of the jerk phase remain scarce, studies indicate that exercises within the clean & jerk group target different segments of the force-velocity spectrum. Takei et al. confirmed this, while Suchomel et al. emphasized the importance of distinguishing between barbell velocity and system velocity in derivative exercises, which is also relevant for jerk performance [37, 40]. Comparative analyses have further shown differences in muscular involvement and body segment contribution between the clean and jerk phases, reflected in the barbell's velocity profile [2, 33].

Squat

The squat is considered a reference exercise in studies on the load-velocity relationship, as its execution allows for precise determination of the association between movement dynamics and training intensity. The mean barbell velocity (MBV) at 1RM is typically around 0.30 m/s, whereas at loads corresponding to 60-80% 1RM, values generally fall within the range of 0.50-0.80 m/s [1, 35]. Numerous studies have confirmed the high validity of predicting 1RM based on submaximal movement velocities [22, 25]. Thompson et al. compared different regression models for estimating 1RM and concluded that while all exhibit moderate validity, prediction accuracy largely depends on the chosen mathematical model, underscoring the need for cautious interpretation [41]. Similar limitations were identified by Kilgallon et al., who demonstrated that velocity metrics – mean propulsive velocity (MPV), mean velocity (MV), and peak velocity (PV) – are highly reliable (CV < 8.8%) in squats performed at 20-90% 1RM, yet regression models systematically over- or underestimated 1RM values, reducing their practical applicability [42]. Moreover, individualized load-velocity (L-V) profiles in the squat have been shown to display high reproducibility and predictive value [19, 20]. The use of the minimal velocity threshold (MVT) provides even greater accuracy in estimating maximal strength compared to group-based average values [6]. Additionally, velocity loss analysis enables prediction of the total number of repetitions that can be performed in a set [12]. With regard to measurement reliability in squats, Grgic et al. confirmed the high test-retest reliability of the GymAware system, reinforcing confidence in PBV and MBV values obtained with this tool [43].

Deadlift

In the deadlift, both mean barbell velocity (MBV) and peak barbell velocity (PBV) are noticeably lower than in squats or Olympic lifts, which directly results from the biomechanical characteristics of this exercise. The absence of the stretch-shortening cycle (SSC), the longer duration of the concentric phase, and the greater demands on trunk stabilization limit movement dynamics compared to other exercises. Studies indicate that at 1RM load, barbell velocity in the deadlift decreases to approximately 0.20-0.25 m/s [14], confirming its nature as an exercise primarily targeting maximal strength development.

At submaximal loads corresponding to 70-80% 1RM, MBV values average 0.35-0.55 m/s, while PBV reaches 0.60-0.80 m/s [15, 18]. These data clearly confirm the predictability and stability of the load-velocity relationship in this lift, although they also highlight its specificity compared to squats and Olympic lifts.

The use of lifting straps significantly affects the accuracy of 1RM prediction, suggesting that grip technique and stabilization method play a role in shaping velocity parameters [18]. This emphasizes the need to standardize measurement conditions if results are to be comparable across studies and athletes. Furthermore, comparisons of mathematical models have shown that individualized regression equations more accurately reflect actual maximal strength than generalized population-based formulas [10]. This underlines the importance of personalization when interpreting velocity measurements in the deadlift.

Recent work by Lopes Dos Santos et al. additionally demonstrated that the load-velocity (L-V) profile can accurately predict 1RM in the hexagonal bar deadlift variant [44]. These findings suggest that alternative exercise variations, such as the hex bar deadlift, may increase the practical applicability of VBT, particularly in monitoring strength and power across different groups of athletes.

Bench Press

The bench press is one of the most extensively studied exercises in the context of velocity-based training (VBT). Its popularity in the scientific literature stems from both the simplicity of execution and the high repeatability of kinematic parameters. Mean barbell velocity (MBV) at maximal load (1RM) typically falls within the range of 0.15-0.20 m/s, while at submaximal loads corresponding to 60-80% 1RM, values increase to 0.35-0.60 m/s [6, 45]. The stability of this relationship between movement velocity and load intensity makes the bench press a widely used reference exercise for developing individual load-velocity profiles and estimating maximal strength. Importantly, research indicates that velocity values correlate strongly and consistently with %1RM regardless of the bench press variation – whether performed on a flat bench, an incline or decline bench, or with a pause in the bottom position [11, 46]. This highlights the universality of the exercise for VBT research and confirms its practical utility for coaches. Furthermore, Ferri Marini et al. demonstrated that both the distribution of weight on the barbell and the velocity of repetitions significantly influence total work volume and the subjective perception of effort during bench press sets. These findings underscore the importance of velocity monitoring not only in load assessment but also in relation to the athlete's perceived exertion, which has practical value when planning training volume and intensity [47]. Subsequent research by Herrera-Bermudo et al. confirmed that the load-velocity profile in the bench press remains stable regardless of grip width. Moreover, the authors showed that the estimation of 1RM (V1RM) and measurement reliability are comparable when using either mean velocity (MV) or mean propulsive velocity (MPV). This suggests that velocity monitoring across grip variations does not require separate interpretative models, thereby simplifying the practical application of VBT in this exercise [48]. Recent comparative analyses further confirmed the high accuracy of 1RM prediction based on both mean and peak velocity, strengthening the methodological foundation for applying such measures in diagnostic and coaching practice [24]. Monitoring velocity loss (VL) during sets has also been identified as an effective tool for assessing fatigue and regulating training volume, allowing adjustment of intensity to specific training goals [27]. It is also noteworthy that technological advancements have enabled velocity measurements to extend beyond laboratory environments. The use of mobile video-analysis applications and inertial measurement units (IMUs) in the bench press has been validated against laboratory-based systems, confirming their high reliability and practical applicability in everyday training practice [23, 25].

Discussion

The present analysis confirms that barbell velocity is a reliable indicator of training intensity in both classical strength exercises and Olympic lifts. The relationship between velocity values and %1RM is well documented and reproducible, making it a useful tool for predicting maximal strength without the need for direct 1RM testing [1, 35, 45]. Miras-Moreno et al., in their meta-analysis, also indicated that barbell velocity measurements can be applied to predict the number of repetitions to failure [49].

One of the main limitations in the field remains the lack of full protocol standardization. Variations in warm-up routines, rest intervals, or movement segmentation can substantially affect velocity outcomes [8, 30]. Studies demonstrate that even minor methodological changes, such as the placement of the measuring device or the use of lifting straps in the deadlift, can alter the interpretation of load-velocity profiles [15, 18].

Another issue concerns the selection of velocity indicators. In classical strength exercises, MBV is most commonly applied due to its stable correlation with %1RM, whereas PBV and MPV are more relevant in Olympic lifts and their derivatives, as they better capture the ballistic nature of these movements [7, 9]. However, discrepancies remain across studies: some authors argue that MBV is more practical for load regulation, while others highlight that PBV provides more meaningful insights into execution quality and power generation [3, 11].

Measurement technologies are also evolving rapidly. On the one hand, linear position transducers (LPTs) continue to serve as the gold standard in scientific research [19, 22]; on the other hand, mobile applications and inertial measurement units (IMUs) are becoming increasingly accessible and reliable in practice [23, 24, 25]. Nevertheless, inter-device differences may reach double-digit percentages, creating challenges when comparing results across studies [27]. Martínez-Cava et al. emphasized that variations in accuracy and repeatability between measurement systems can significantly influence data interpretation, complicating cross-study comparisons [50].

From a training perspective, the application of VBT holds substantial value in both the periodization of elite athletes and in recreational settings. Load-velocity profiling enables autoregulation of training that accounts for daily fluctuations in readiness [4, 5]. Research also shows that monitoring velocity loss within a set is an effective method of controlling fatigue and adjusting training volume, contributing to improved long-term adaptations [12, 26]. However, it is worth noting that the effectiveness of VBT may differ depending on the athlete's training level: in elite lifters, the method requires greater precision, whereas in amateurs it may serve as an educational and motivational tool [13].

The growing body of systematic reviews and meta-analyses also points to the robustness of this approach. Findings suggest that velocity-based training is at least as effective as traditional methods for developing strength and power, and often confers additional benefits related to fatigue management and improvements in explosive performance [5, 10, 13, 51]. For instance, Baena-Marín et al. confirmed in their meta-analysis that VBT effectively enhances both maximal strength and power capacities, underscoring its broad applicability in sport practice.

Conclusions

Barbell velocity represents a practical and valuable indicator in both strength training and Olympic weightlifting. It demonstrates a strong and reproducible relationship with %1RM, enabling reliable estimation of maximal strength and effective regulation of training intensity without the need for maximal testing. Its application supports periodization, autoregulation of loads, and monitoring of readiness to perform.

However, the lack of standardized research protocols – particularly regarding warm-up procedures, rest intervals, movement segmentation, and measurement device placement – limits the comparability of findings across studies. Furthermore, differences between measurement technologies highlight the need for caution when interpreting results and reinforce the necessity of validating tools within specific contexts.

Future research should focus on the standardization of measurement procedures and the validation of velocity-based tools across diverse athletic populations. Establishing clear methodological guidelines will enhance the reliability of barbell velocity as a diagnostic and training tool, thereby strengthening its role in both scientific research and coaching practice.

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