Reliability and validity of the MetricVBT application (v0.3)

Study details

Conducted by: Core Advantage Pty Ltd, creators of MetricVBT

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Location: TrackLab motion capture studio, Yarraville, Victoria, Australia 3013

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Abstract

The purpose of this study is to assess the validity and reliability of the *MeticVBT* smartphone app (Core Advantage, Melbourne, Australia) to track typical barbell exercises at fast and slow movement velocities using a motion capture system as a baseline.

A smartphone device (iPhone XS max, Apple, California) was positioned side on to the subject to record all sets, while a motion capture system (MOCAP) (NaturalPoint, Inc., Oregon) consisting of 24 x *OptiTrack* Cameras for tracking, and accompanying processing software, *Motive 3* simultaneously collected raw positional data. The subject completed two (2) sets of eight (8) repetitions for the deadlift, front squat, and bench press exercises completing a total of 48 repetitions. Each exercise was

completed for a controlled, slow set (TEMPO) and a maximum effort, fast set (MAX). All sets were completed with 40kg.

The video footage from the smartphone and the MOCAP positional data was then analysed using the MetricVBT (v0.3) algorithm to count repetitions (reps) and calculate mean concentric velocity (VEL), and concentric range of motion (ROM) for every rep.

Overall validity for both VEL and ROM were calculated by correlation between the Smartphone device video footage with the MOCAP data. Reliability was assessed through repetition count and using absolute differentials and percentage variation for VEL and ROM from the MOCAP baseline.

MetricVBT was able to accurately detect 48/48 repetitions from the smartphone footage with no missed or additional “phantom” reps recorded.

The smartphone footage and MOCAP data had a correlation of R=0.9862 for ROM and R=0.9841 for VEL.

The MetricVBT v0.3 smartphone application was able to accurately and consistently detect repetitions and analyse concentric mean velocity and range of motion from video footage with a high correlation to the MOCAP object tracking system across the fast and slow repetitions for all three exercises.

These findings indicate that MetricVBT is a valid and reliable solution for velocity based training on strength exercises performed at both a fast and slow velocity.

Introduction

Despite the growing support and interest in the use of velocity in the weight room there remains a generally low rate of adoption for VBT across the wider resistance training community. Cost (either financial or time), lack of knowledge, informational overwhelm, and user experience issues when implementing technology leaves many unable to incorporate velocity into their training despite their desire to do.

There remains a need for simple, affordable solutions to tracking velocity in the gym. It is within this context that the *MetricVBT* (Core Advantage, Melbourne, Australia) application has been developed. Utilising only a smartphone device and the inbuilt camera system, MetricVBT works by way of a sophisticated computer vision algorithm specifically designed to recognise, track and calculate the displacement and velocity of barbell movements with regulation weight plates.

Many tried-and-tested technologies have been proven to be able to provide valid and reliable velocity data. Established technologies include Linear positional transducers,

wearable accelerometers, and rack mounted camera systems are all valid approaches utilising specialised hardware and application interfaces (Martínez-Cava A, et al, 2020, Pérez-Castilla A, et al, 2019, Tomasevicz C, et al, 2020)

Some commercially available applications offer general exercise tracking but none can automatically detect and count multiple repetitions within a single set and provide accurate data with device placements outside highly exacting positions. To our knowledge, there does not exist a smartphone application which can automatically, reliably, and precisely measure velocity from a range of smartphone device positions without user input.

Precise computer vision possesses many key advantages over existing velocity tracking technologies.

- Simultaneously recording video of the exercise enables sharing and technique review
- Video data can be additionally processed with other ML tools such as pose estimation for joint angle analysis
- No additional hardware needs to be purchased
- No devices need to be attached to the barbell or lifter

The lack of impediment in implementing velocity tracking offered by phone-based computer vision may dramatically increase the uptake of VBT.

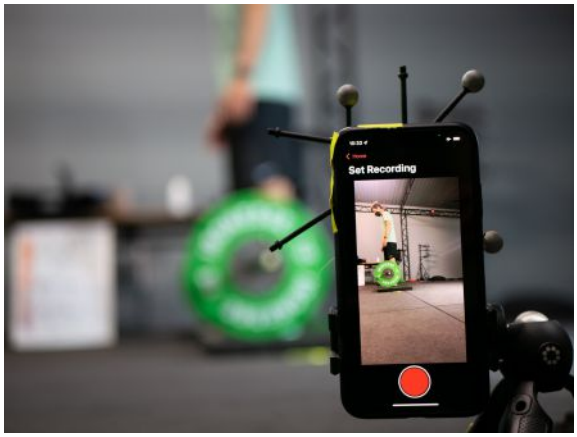
The aim of this validation study is to asses the validity and reliability of the *MetricVBT* beta application (v0.3) in analysing typical strength exercises at both fast and slow velocities. An optical 3D motion sensing system (MOCAP) being used as the reference method.

Method

Subject

A single male participant (age: 30 years, height: 193cm, body mass: 93.2kg) was utilised in this study. The participant was fit and healthy, with 10+ years of strength training experience and familiarity on the exercises.

Bench press being performed with smartphone devices recording in the background.

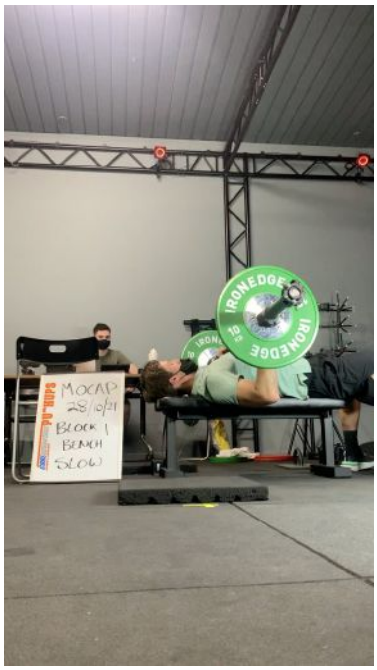


Perspective and framing from the smartphone device placement.

Design

A single data collection day was conducted with the participant performing three common strength exercises; A conventional Deadlift, Front Squat and Bench Press. All exercises were completed with a submaximal load (40kg, approximately ~30-40% of 1RM). Each exercise was performed for two (2) sets of eight (8) repetitions. The first set at a slow movement speed (TEMPO) while on the second set the participant was instructed to perform the concentric portion of each repetition as fast as possible (MAX).

A total of 48 repetitions were included in the study across six sets.



Data collection

Raw positional data was captured using the MOCAP system, with a single marker in the exact centre point of the barbell end, this was recorded at a sampling rate of 120Hz.

Video was captured using a smartphone device (iPhone XS, Apple*,* California) using the in-built camera application. Recording was completed in a vertical orientation at 1080p resolution (HD) with the 60 frames per second (60fps) setting enabled. The smartphone device was positioned approximately 2.5 metres directly from the end of the barbell with the device at waist height in a tripod.

Analysis

Video footage from the smartphone device was processed by the *MetricVBT* application (version 0.3 - beta), range of motion (ROM) and mean concentric velocity (VEL) data was then collected for all repetitions. The raw MOCAP positional data was converted into VEL and ROM data using the same stop and start threshold settings as the video footage.

Results

Raw data for all repetitions can be found in Appendix A at the bottom of this paper.

Rep count:

Both the processed smartphone device footage and converted MOCAP data correctly identified and were able to count all performed repetitions with the MetricVBT algorithm. No missed reps or additional (often called “phantom” reps) were reported by either system.

Data Correlation for ROM and VEL:

Using the MOCAP system as a baseline, the MetricVBT processed footage reported a very high correlation for both ROM (R =0.9862) and VEL (R =0.9841).

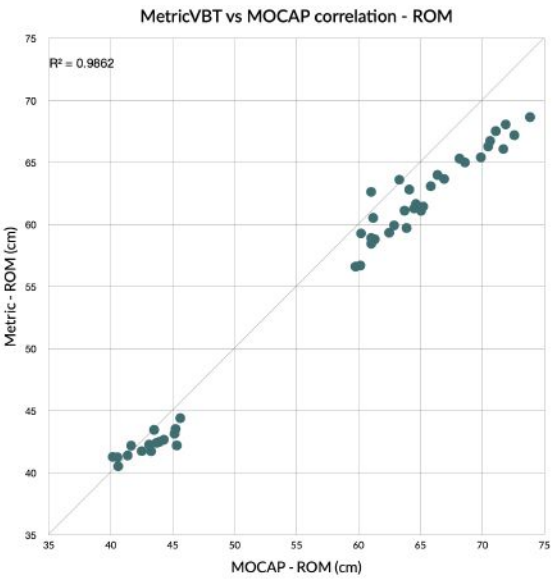


Fig 1: ROM Correlation for all repetitions. Angled line represents a perfect 1.0 correlation.

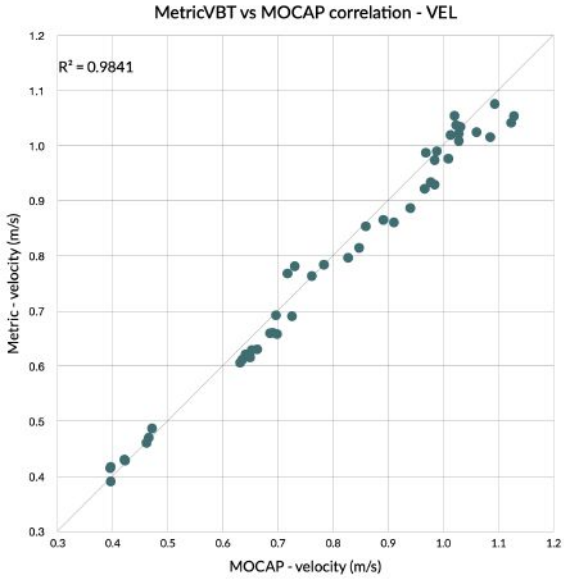


Fig 2: VEL Correlation for all repetitions. Angled line represents a perfect 1.0 correlation.

Absolute differentials:

On a rep-by-rep analysis, MetricVBT reported an average differential of 0.02m/s (2.51%) for VEL and 2.27cm (3.91%) for ROM. The spread of differentials between MetricVBT and the MOCAP data was -0.00m/s to +0.08m/s (0.0% to 7.2%) for VEL and 0.04cm to 5.6cm (0.1% to 7.8%) for ROM.

Range of motion (cm) differential - set averages

	MOCAP		MetricVBT		Differential	
Exercise	M vel (m/s)		M vel (m/s)		± (m/s)	± (%)
Averages	**58.07**		**55.80**		**-2.27**	**-3.91%**
Deadlift - slow	61.11		59.22		-1.90	-3.1%
Deadlift - fast	63.60		61.15		-2.44	-3.8%
Front squat - slow	66.01		62.90		-3.11	-4.7%
Front squat - fast	71.50		66.99		-4.51	-6.3%
Bench - slow	41.69		41.69		0.00	0.0%
Bench - fast	44.53		42.88		-1.65	-3.7%

Table1: Set by set summary for ROM data

Mean velocity (m/s) differential - set averages

	MOCAP		MetricVBT		Differential	
Exercise	**M vel (m/s)**		**M vel (m/s)**		**± (m/s)**	**± (%)**
Averages	**0.80**		**0.78**		**-0.02**	**-2.51%**
Deadlift - slow	0.72		0.72		0.00	0.0%
Deadlift - fast	1.06		1.02		-0.04	-3.8%
Front squat - slow	0.66		0.63		-0.03	-4.6%
Front squat - fast	0.91		0.87		-0.03	-3.3%
Bench - slow	0.43		0.44		+0.01	2.3%
Bench - fast	1.01		1.01		0.00	0.0%

Table2: Set by set summary for VEL data

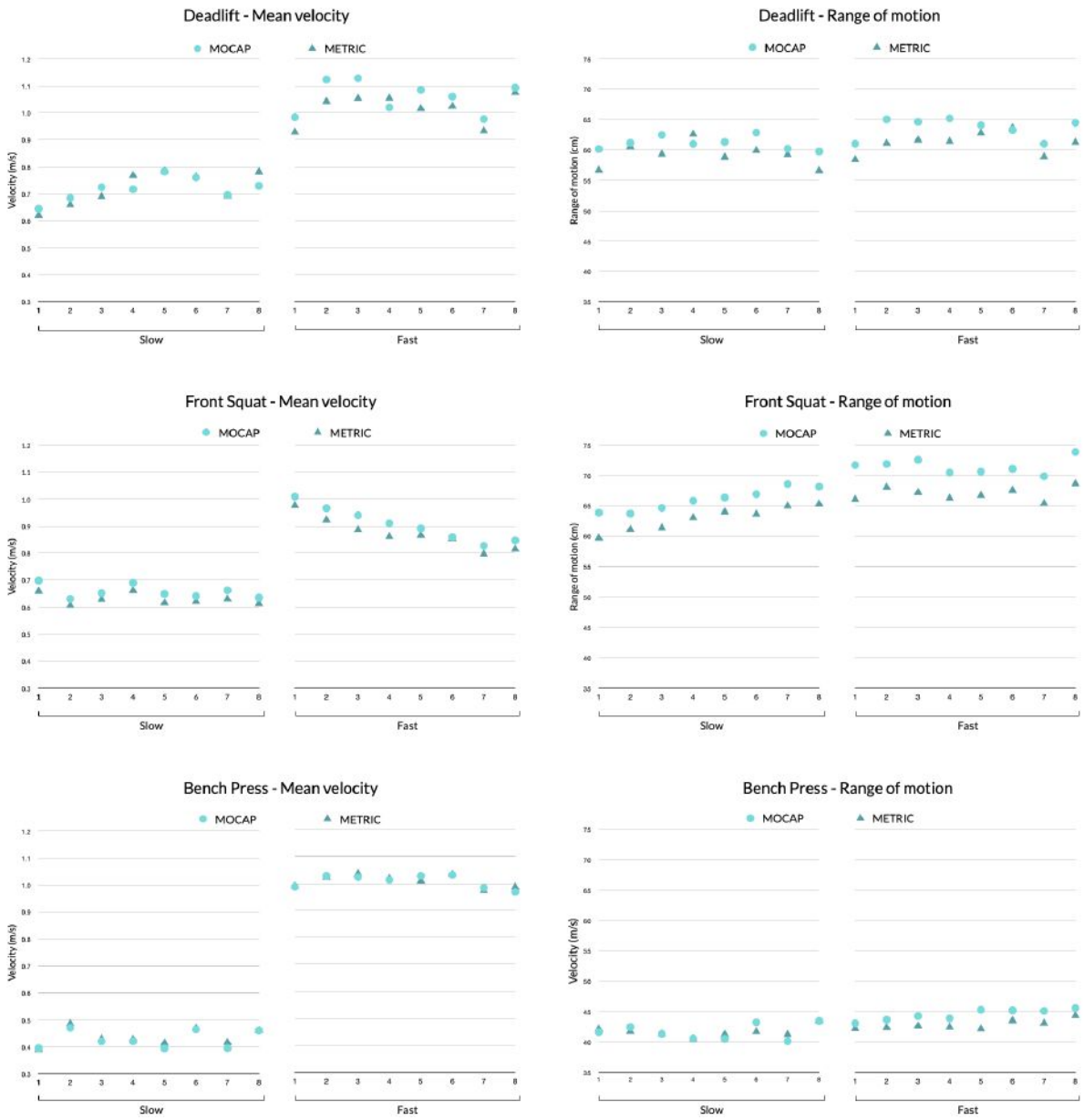


Fig 3: VEL and ROM results for each individual repetition seperated by exercise and condition for metricVBT and MOCAP.

Discussion

Our results show that MetricVBT v0.3 is able to accurately detect repetitions and analyse concentric mean velocity and range of motion for standard strength exercises.

To be useful, a measurement device needs to be both valid and reliable. The user must get data that is relevant to the real-world, and get it repeatedly.

Metric v0.3 has shown it is able to achieve both these objectives with a tight correlation to the results produced by the MOCAP system across a range of

velocities for the tested exercises.

While Metric did under-report both VEL and ROM on almost all repetitions, it was able to do this within a tight range (no outlier repetitions occurred). These findings mean users can be confident that results from MetricVBT are reflective of a change in performance and not due to measurement error.

It is worth stating that the Metric algorithm is less than a year old and is continuously improving as we invest in further research and development.

To us it seems inevitable that velocity based training using computer vision will be the obvious choice for most practitioners in the future. Computer vision apps are easy to use, cost effective, and portable.

Even though Metric is a novel technology and still in it's Beta stages of development, it's simplicity in use and negligible cost make it a compelling option for coaches and athletes at all levels looking to incorporate velocity into their training.

Further validation needs to be conducted to explore the ability of MetricVBT to measure more diverse movements, including ballistic movements like the Olympic lifts. MetricVBT also needs to be validated in a wider range of smartphone devices and phone placement positions.

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Appendix

Raw rep-by-rep data

Appendix 1: Raw data

		Concentric mean velocity m/s (VEL)		Range of Motion cm (ROM)	
Exercise	**Rep #**	**MOCAP**	**METRIC**	**MOCAP**	**METRIC**
	Averages	**0.80**	**0.78**	**58.1**	**55.8**
Deadlift - slow	1	0.65	0.62	60.1	56.7
	2	0.69	0.66	61.2	60.5
	3	0.73	0.69	62.5	59.3
	4	0.72	0.77	61.0	62.6
	5	0.78	0.78	61.3	58.8
	6	0.76	0.76	62.9	59.9
	7	0.70	0.69	60.2	59.3
	8	0.73	0.78	59.8	56.6
Deadlift - fast	1	0.98	0.93	61.0	58.4
	2	1.12	1.04	65.0	61.1
	3	1.13	1.05	64.6	61.6
	4	1.02	1.05	65.2	61.4
	5	1.09	1.02	64.1	62.8
	6	1.06	1.02	63.3	63.6
	7	0.98	0.93	61.0	58.9
	8	1.09	1.08	64.5	61.3
Front squat - slow	1	0.70	0.66	63.9	59.7
	2	0.63	0.61	63.7	61.1
	3	0.65	0.63	64.6	61.4
	4	0.69	0.66	65.8	63.1
	5	0.65	0.62	66.4	64.0
	6	0.64	0.62	66.9	63.7
	7	0.66	0.63	68.6	65.0
	8	0.64	0.61	68.1	65.3
Front squat - fast	1	1.01	0.98	71.7	66.1
	2	0.97	0.92	71.9	68.1
	3	0.94	0.89	72.6	67.2
	4	0.91	0.86	70.5	66.3
	5	0.89	0.87	70.6	66.7
	6	0.86	0.85	71.1	67.5
	7	0.83	0.80	69.9	65.4
	8	0.85	0.81	73.8	68.6
Bench - slow	1	0.40	0.39	41.6	42.2
	2	0.47	0.49	42.5	41.7
	3	0.42	0.43	41.4	41.4
	4	0.42	0.43	40.6	40.5
	5	0.40	0.41	40.5	41.2
	6	0.47	0.47	43.3	41.7
	7	0.40	0.42	40.2	41.3
	8	0.46	0.46	43.5	43.4
Bench - fast	1	0.99	0.99	43.1	42.3
	2	1.03	1.02	43.7	42.4
	3	1.02	1.04	44.3	42.7
	4	1.01	1.02	43.9	42.5
	5	1.03	1.01	45.3	42.2
	6	1.03	1.03	45.2	43.5
	7	0.98	0.97	45.1	43.1
	8	0.97	0.99	45.6	44.4