The Deceleration Paradox:
The faster you run the slower you stop

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Abstract

This study examined the effect of approach momentum on horizontal deceleration (DEC) performance. Eighty team sports athletes performed three maximal horizontal DEC trials from a 15 m approach. Sprint performance was recorded using timing gates and instantaneous velocity was collected using a radar device. Correlation and multiple regression analysis were conducted to analyze the relationships between DEC-related variables. Between-subject (top 50% vs. bottom 50%) differences in DEC-related variables were also determined. Greater mean DEC was significantly correlated with lower approach momentum (r = -0.354, p = 0.001). Compared to lower DEC performers (in terms of mean and peak values), greater performers showed statistically significantly lower peak approach velocity (ES = 0.41-0.66, p < 0.05) and lower peak approach momentum (ES = 0.48-0.60, p < 0.05). Furthermore, the standardized Beta values of the multiple regression analysis demonstrated that body mass is a greater determinant of DEC performance compared to approach velocity. In conclusion, practitioners should be aware that approach momentum (body mass and approach velocity) is a factor influencing DEC performance, and an inverse relationship exists. Thus, to evaluate maximal DEC ability, approach velocity and body mass must be considered.

Keywords: braking; body mass; peak velocity

Word count: 3413

Introduction

Horizontal deceleration (DEC) has been identified as the ability to rapidly reduce horizontal velocity and is typically featured in team sports such as rugby (4) and football (21), underpinning movements such as sharp stops, changes of direction, and transitions between attack and defense. In a football match, players commonly perform ~ 195 DECs at < -2 m/s^2 and ~ 46 at < -3 m/s^2 (4). Moreover, the demand for high-intensity (< -3 m/s^2) DECs is greater than high-intensity accelerations (> 3 m/s^2) in team sports matches (4), given the need to brake rapidly from high-speed sprinting (4), with rolling starts often negating the need to accelerate above the predefined threshold. In football for example, players in all positions exhibited greater intensity during DECs (-5.7 to -6.3 m/s^2) than accelerations (4.4 to 4.7 m/s^2) (4), where the intention of the former, perhaps more so than the latter, is to evade or track opponents to create favorable positions (10). Therefore, there is a need to assess the horizontal DEC ability of athletes to provide insights into training programs and player development.

Horizontal DEC performance has been extensively investigated using change of direction (COD) (5,6,25) and acceleration-to-deceleration ability (ADA) tests (9,12,26). Compared to COD tasks, the ADA test is seemingly more applicable for assessing maximal horizontal DEC, as it does not require the execution of directional change maneuvers. The ADA test includes a set pre-determined distance for acceleration followed by the requirement to stop as quickly as possible (15),with variables such as mean and peak DEC, and time and distance to stop routinely used to assess performance (11,12,26).

Deceleration involves negative changes in horizontal velocity to bring an athlete to a stationary position from peak approach momentum. Thus, from a mechanical perspective, DEC performance is influenced by body mass and approach velocity. Moreover, based on the impulse-momentum relationship and Newton's second law of motion ($\boldsymbol{F} = m\boldsymbol{a}$), improvements in DEC are determined by the amount of braking force applied over time, with more force required for greater approach velocities or increases in body mass. Therefore, theoretically, an athlete attempting to decelerate from a greater approach momentum, whether a consequence of greater mass or velocity, may require a longer duration and distance over which to stop, compared to a lower approach momentum. This is likely on account of a greater number of foot contacts required to generate a sufficient braking impulse to progressively reduce the horizontal momentum, with each athlete only able to tolerate so much load per footstep.

The ability to effectively reduce momentum is crucial for achieving rapid braking. However, the current literature is limited in its consideration of the relationship between momentum and deceleration capability. Therefore, the purpose of this study was to investigate the effect of approach momentum on horizontal DEC performance. It was hypothesized that approach momentum would be a crucial determinant contributing to the discrepancy between greater and lower DEC performers, and approach momentum would be inversely correlated with DEC performance.

Methods

Experimental Approach to the Problem

A cross-sectional and correlative research design was used to investigate the correlations and between-subject (top 50% vs. bottom 50%) differences between horizontal DEC performance and approach momentum (including the independent analysis of body mass and approach velocity) in collegiate football and rugby athletes. The velocity-time profile was recorded using a radar device, whilst linear sprint times were measured using timing gates. Mean DEC, peak DEC, time, and distance to stop were used to assess horizontal DEC performance. All tests were performed during the pre-season period.

Subjects

Eighty male university athletes from team sports (football: n = 50, rugby: n = 30, Division-I collegiate football and rugby athletes) were recruited (age: 23.14 ± 0.21 yrs; height: 1.81 ± 0.67 m; body mass: 71.81 ± 2.23 kg; relative back squat 1RM: 1.88 ± 0.32 body mass, 4.89 ± 1.23 training sessions/week, 12.62 ± 5.23 yr of specific sports experience) and were classified as trained or developmental subjects (22). A minimum sample size of 68 was required from a pre-determined power analysis using G-Power (G*Power 3.1.9.7, University Düsseldorf, Düsseldorf, Germany) according to an effect size of 0.33 (a reported correlation value between horizontal deceleration and momentum) (12), a power of 0.85, and alpha level of 0.05. To meet the inclusion criteria in this study, all players had a minimum of 3 years of experience in their respective specific sports (football and rugby), had a minimum of 2 years resistance training experience, and had no experience of serious injury 6 months before testing. Testing was performed in the pre-season period and all participants provided written informed consent to participate. Participants were instructed to refrain from strenuous exercise and any performance-enhancing substances 72 hours before measurement. This study was approved by the ***** Ethics Review Board.

Procedures

Following a 10 min warm-up session consisting of 5 min of jogging and 5 min of selected dynamic stretching (Bodyweight Squat: 20 repetitions, Side Lunge: 215 repetitions each leg, Hip Extension: 15 repetitions each leg, Hip Rotation: 10 repetitions each leg, Spider-man Step: 10 repetitions each leg, Skipping: 30 seconds), subjects performed 6 familiarization trials including 3 linear sprint trials and 3 horizontal DEC trials at submaximal effort (75% of perceived maximum effort). After 5 minutes of recovery, subjects performed 15 m linear sprint tests followed by maximal horizontal DEC tests, with 2–3 minutes of within-test intervals and 5 minutes of between-test intervals. All tests were conducted on an indoor synthetic athletics track under the supervision of two PhD candidates who were NSCA certified strength and conditioning specialists.

Linear Speed and Maximal Horizontal DEC Test

The completion time of a 15 m linear sprint was collected using timing gates (Version 4.0, Fusion Sport Pty Ltd, Coopers Plains, Queensland, Australia) with a height of 0.8 m (3). All participants started 0.3 m behind the starting line with a two-point staggered start position and were required to undertake three sprint trials, each as fast as possible. The best of the three sprint trials was used as a reference to determine whether a DEC trial was conducted with sufficient sprint speed, thus preventing premature braking occurring during the DEC task.

During the acceleration-deceleration test, all participants were instructed to reduce their horizontal velocity to zero as quickly as possible following a 15 m linear sprint (Figure 1). Following DEC, all participants were required to backpedal to the DEC line to determine the end position of DEC. All participants were instructed not to decelerate until passing the 15 m line, and the 15 m completion time of any trial that was 5 % greater than the individual best sprint time was discarded (15) and subsequently another trial was performed following 2-3 min recovery. The completion time of the 15 m sprint was recorded using the aforementioned timing gates and the velocity-time-distance profile was collected using a radar device (Stalker ATS II, Applied Concepts, Inc., Dallas, TX, USA), which was positioned 5 m behind the starting line at a height of 90 cm and sampling at 47 Hz. Three successful trials were collected for each participant.

*** Please insert Figure 1 here *(see end of paper)* ***

Data Analysis

All data were manually processed using the Stalker ATS system, as per previous research (15), and then exported to Microsoft Excel. This included removing all data collected prior to the commencement of the sprint and following the DEC phase, and removing unexpectedly high/low data on the velocity-time profile that were likely caused by segmental moments of the participants while sprinting.

The initial and end point of the DEC phase was defined as the instantaneous velocity of the 15 m position (Vpeak) and the lowest instantaneous velocity following Vpeak, respectively. The instantaneous DEC during the DEC phase was determined using Equation 1 (linear adjacent method):

$$\text{DEC (m/s}^2\text{)} = (Vf - Vi) / (Tf - Ti) \quad \text{(Equation 1)}$$

Where *V* is velocity, *T* is time, *f* is final time or velocity, and *i* is the initial velocity or time.

DEC variables were analyzed including: 1) mean DEC, the average of all instantaneous DEC values during the DEC phase, 2) peak DEC, the highest instantaneous DEC values during the DEC phase, 3) time to stop, time over the whole DEC phase, 4) distance to stop, distance covered during whole DEC phase (15).

Statistical Analyses

Descriptive data were presented as mean ± SD and normality was determined using the Shapiro-Wilk's test. For the assessment of reliability, and given our repeated measures design, a two-way mixed effects intraclass correlation model was used, where both the reliability of a single (best) trial (ICC [3,1]) and the average of three trials (ICC [3,k]) were assessed. Furthermore, the coefficient of variation (CV %) was also calculated, thus providing us with a measure of relative and absolute reliability, respectively; 95% confidence intervals for all reliability results were reported. The ICCs were interpreted as per the following scale: poor (≤ 0.49), moderate (0.50-0.74), high (0.75-0.89), and near perfect (≥ 0.90) (17). The CV% values of < 5%, 5 ~ 10%, 10 ~ 15%, and > 15% were interpreted as excellent, good, moderate, and poor, respectively (23). Furthermore, the combination of the ICC and CV% enabled the interpretation of overall reliability as follows: excellent (ICC > 0.9 and CV% < 5), good (0.75 < ICC ≤ 0.9 and CV% < 10), fair (ICC ≤ 0.75 or CV% > 10) and poor (ICC ≤ 0.75 and CV% < 10) (14).

The correlational analyses were examined using Pearson's (parametric data) or Spearman's (non-parametric data) correlations. The correlation coefficients were interpreted as per the following scale: trivial (< 0.1), small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9), and near perfect (> 0.9) (16). Multiple regression analysis was used to determine the relationship of approach velocity and body mass (independent variables) with mean and peak DEC (dependent variables). Significance and relative contribution of predictors were examined using standardized Beta values and *t*-statistics.

Between-subject (top vs bottom 50 %) differences in DEC variables between greater and lower athletes (mean DEC, peak DEC, and approach momentum) were determined using independent samples *t*-test (parametric) or Mann-Whitney U tests (non-parametric). Effect sizes (Cohen's *d*) were conducted to assess the magnitude of differences and were interpreted as trivial (< 0.19), small (0.20 - 0.49), moderate (0.50 – 0.8), large (0.8 - 1.2), and very large (> 1.2) (2). All statistical procedures were performed with SPSS software (Version 22.0, IBM Corp., Armonk, NY, USA) and significance was set at $p < 0.05$.

Results

All variables showed moderate to good overall reliability (Table 1). Specifically, peak and mean DEC displayed good overall reliability, while peak approach velocity, peak approach momentum, time to stop, and distance to stop showed moderate overall reliability (Table 1).

*** Please insert Table 1 here *(see end of paper)* ***

Lower peak approach momentum was significantly and moderately correlated with greater mean DEC ($r = -0.354$, $p = 0.001$) and greater peak DEC ($r = -0.323$, $p = 0.001$) (Table 2).

*** Please insert Table 2 here *(see end of paper)* ***

Comparisons of greater vs. lower peak DEC performers demonstrated that greater performers statistically significantly exhibited greater mean DEC ($p < 0.001$, ES = -2.45), lower peak approach momentum ($p = 0.037$, ES = 0.48), and lower peak approach velocity ($p = 0.021$, ES = 0.66), with small to very large effect sizes. Moreover, non-significant differences with small effect sizes were observed in body mass ($p = 0.258$, ES = 0.25), and time ($p = 0.126$, ES = 0.37) and distance ($p = 0.055$, ES = -0.43) to stop between greater and lower performers (Table 3).

*** Please insert Table 3 here *(see end of paper)****

Comparisons of greater vs. lower mean DEC performers showed that greater performers statistically significantly displayed greater peak DEC ($p < 0.001$, ES = -2.55), lower peak approach velocity ($p = 0.046$, ES = 4.1), lower peak approach momentum ($p = 0.009$, ES = 0.60) and distance to stop ($p = 0.044$, ES = -0.46), with small to very large effect sizes. Non-significant differences with small effect sizes were observed in body mass ($p = 0.057$, ES = 0.43) and time to stop ($p = 0.196$, ES = 0.29) between greater and lower performers (Table 3).

Comparisons of greater vs. lower approach momentum performers revealed that players with greater approach momentum statistically significantly exhibited lower mean ($p = 0.004$, ES = 0.67) and peak ($p = 0.007$, ES = 0.62) DEC, with moderate effect sizes. Non-significant differences were observed in time ($p = 0.237$, ES = -0.26) and distance ($p = 0.348$, ES = -0.21) to stop, and approach velocity ($p = 0.167$, ES = -0.33), with small effect sizes.

Moreover, greater approach momentum players statistically significantly exhibited greater body mass ($p < 0.001$, ES = -2.33) and approach momentum ($p < 0.001$, ES = -2.85), with very large effect sizes (Table 3).

Comparisons of greater vs. lower approach velocity performers revealed that players with greater approach velocity statistically significantly exhibited lower mean ($p = 0.006$, ES = 0.63) and peak ($p = 0.008$, ES = 0.60) DEC, and peak approach momentum ($p = 0.004$, ES = -0.66), with moderate effect sizes. Non-significant differences were observed in body mass ($p = 0.913$, ES = -0.02), and time ($p = 0.462$, ES = -0.16) and distance ($p = 0.741$, ES = 0.08) to stop, with trivial effect sizes (Table 3). Moreover, comparisons between greater vs. lower body mass performers indicated statistical significance in peak approach momentum ($p < 0.001$, ES = -1.348), with a very large effect size (Table 3).

The results of the multiple regression model are presented in Table 4 and was found to be significant for predicting mean DEC (F = 11.039, $p < 0.001$, $R^2 = 0.203$) and peak DEC (F = 8.122, $p < 0.001$, $R^2 = 0.153$), but not for time and distance to stop ($p > 0.05$). The standardized Beta values of multiple regression analysis demonstrated that body mass is a more key determinant of (mean and peak) DEC performance than peak approach velocity.

*** Please insert Table 4 here *(see end of paper)* ***

Discussion

This study aimed to examine the effect of approach momentum on horizontal DEC performance. The primary findings of this study are that greater momentum is statistically significantly and moderately correlated with lower mean DEC and lower peak DEC. That is to say that the greater the momentum going into the DEC task, the worse the DEC performance will be and as such, an inverse relationship between them exists. Therefore, horizontal DEC performance is dependent on the magnitude of approach momentum, which must be considered when assessing DEC ability. Furthermore, multiple regression analysis revealed that body mass was the largest predictor of DEC performance. In summary, coaches should consider approach momentum when classifying players as faster or slower DEC performers, as direct comparisons using mean/peak DEC may lead to erroneous conclusions regarding DEC ability.

All variables in this study showed acceptable overall reliability with the magnitude ranging from moderate to good. Mean DEC (ICC = 0.79, CV% = 2.46) and peak DEC (ICC = 0.88, CV% = 6.78) showed a good level of consistency between consecutive trials (Table 1). Harper et al. (15) found similar intra-day reliability of mean DEC (ICC = 0.87, CV% = 5.2) and peak DEC (ICC = 0.55, CV% = 9.6). Notably, the moderate inter-day reliability of mean (ICC = 0.73, CV% = 8.0) and peak (ICC = 0.61, CV% = 7.9) DEC reported by Harper et al. (15) may be associated with the neuromuscular fatigue caused by high-intensity DEC tasks. Therefore, these studies suggest that the ADA test using radar gun provides a good intra-day reliability to evaluate the horizontal DEC ability of athletes.

In the current study, athletes with greater approach momentum exhibited statistically significantly lower mean and peak DEC compared to athletes with lower approach momentum (Table 3). Moreover, moderate correlations were observed between peak approach momentum and mean and peak DEC (Table 2). Accordingly, whilst DEC ability is influenced by physical capabilities such as eccentric strength and technical ability (13), it seems that DEC performance is also dependent on the magnitude of approach momentum (that is, peak approach velocity and body mass), thus supporting our hypothesis. During a COD task, Fernandes et al. (7) reported that a greater COD deficit (indicating poorer COD performance) was similarly consequent to greater approach momentum and slower 505 performance. Similar findings were also found in Zig-zag (8,20), Pro-agility (8), and L-drill tasks (8). There are limitations in these studies however, as participants were classified as greater or lower performers according to sprint time rather than peak velocity during the COD task. Thus, by not assessing instantaneous velocity during the COD tasks, it cannot be concluded that athletes with faster linear speed and momentum also displayed greater approach velocities and momentum during the COD tasks. Given DEC performance is largely determined by approach momentum (18,19), the influence of this must be considered when assessing DEC performance. Therefore, several key variables, including those we have highlighted here, must be considered when inferring DEC capacity.

Additional variables to consider include braking strategies such as increasing the horizontal-vector ground reaction force by increasing the distance between the center-of-mass and center-of-pressure. In previous work we have shown this to improve DEC performance (18), however, we do acknowledge that to sit back requires an increase in knee flexion and thus an increase in ground contact time, which in turn is limited by an athlete's capacity to tolerate load. As such, this technique is likely governed by eccentric strength. While it is logical to suggest that eccentric training can target braking strength and thus deceleration performance, it should be noted that this mode of training is likely to also result in increasing in approach velocity and momentum, therefore, DEC performance may remain the same. For example, increases in eccentric strength will inevitably improve the braking phase at ground contact while sprinting (thus likely reducing ground contact time and further invoking the stretch-reflex), and given improvements in eccentric strength are not independent of improvements concentric strength, it will also serve to increase the propulsive phase too.

The standardized Beta values of multiple regression analysis demonstrated that body mass is a greater determinant of DEC performance than peak approach velocity (Table 4) and comparisons between greater and lower DEC performance further supported this (Table 3). For example, we noted that greater approach momentum athletes exhibited non-significant differences in peak approach velocity ($p = 0.167$, ES = -0.33), while demonstrating significantly greater body mass ($p < 0.001$, ES = -2.33). This was also supported by the comparison between heavier and lighter athletes, which indicated that heavier athletes have significantly greater approach momentum (Table 3).

Only a small correlation was observed between maximal approach velocity (mean and peak) and DEC performance (*r* = -0.271 and -0.245) (Table 2). In contrast, Harper et al. (12) reported a very large correlation between mean DEC performance (but a non-significant correlation with peak DEC), but notably, also reported trivial difference in body mass. Under similar circumstances, we found that for athletes with trivial differences in body mass, faster sprint athletes showed significantly lower (mean and peak) DEC performance than slower sprint athletes (Table 3). Therefore, approach velocity is likely a key factor influencing DEC performance between athletes of similar mass.

The findings of this study demonstrated that horizontal DEC performance is determined by the magnitude of approach momentum, which should be considered when assessing DEC ability. However, several limitations should be acknowledged. First, the present study only analyzed DEC following a 15 m acceleration and thus different association to performance may be found with shorter or longer approaches and thus lower or higher approach momentums respectively. That said, based on fundamental mechanics, our hypothesis would not change. Second, the importance of muscle strength (especially eccentric strength) and deceleration skill on DEC performance should be considered to determine their impact on performance. Therefore, further research is needed to examine how variations in acceleration distance, and thus approach momentum, affect DEC performance, as well as to identify the optimal deceleration capacities and skills.

Practical Applications

We found a good level of reliability in measuring mean and peak DEC using radar gun, but moderate reliability for time and distance to stop. Thus, mean and peak DEC are recommended as appropriate variables for assessing DEC performance and a radar gun can be used to measure instantaneous velocity during the ADA test.

When assessing deceleration performance, practitioners must also consider approach velocity and body mass, as an inverse relationship clearly exists and is likely an unavoidable paradox of deceleration testing. To support our conclusion, we have provided a worked example using calculations of momentum. Consider athlete A with an approach velocity of 7 m/s and a body mass of 78 kg (thus a momentum of 546 kg·m/s), compared to athlete B with the same body mass but a slower approach velocity of 5 m/s (390 kg·m/s). Player B is more likely to decelerate over a shorter distance and time interval as they have less impulse to generate to overcome their inertia. Similarly, if player A and B have the same approach velocity of 7 m/s but differing body masses of 90 and 70 kg respectively, then the greater impulse of A (630 kg· m/s) compared to B (490 kg· m/s) will again mean that athlete B will outperform athlete A when considering deceleration in isolation. While it is tempting to suggest athlete A could compensate for their increased approach velocity and/or body mass via training to increase force application during the braking phase, we would speculate that any training (eccentric or otherwise) that leads to a greater capacity to generate negative acceleration, would also serve to increase positive acceleration and in effect, potentially cancel each other out. Beyond improvements in technique, which is likely limited as the capacity to sit back is logically based on force capacity, perhaps a reduction in non-functional body mass may be the best way for athlete A to contend with the performance of athlete B in time and distance to stop. Of course, in some sports, such as rugby, body mass clearly defines positional demands, so an athlete's power to weight ratio will always be a determining factor.

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Table 1. Descriptive data of deceleration performance

	Mean ± SD	ICC (95% CI)	CV %	Magnitude
M-DEC (m/s^2)	4.17 ± 1.79	0.79 (0.66, 0.89)	2.46	Good
P-DEC (m/s^2)	5.37 ± 2.44	0.88 (0.80, 0.94)	6.78	Good
P-A-V (m/s)	7.22 ± 0.30	0.66 (0.47, 0.80)	5.76	Moderate
P-A-M (kg· m/s)	506.84 ± 55.23	0.65 (0.45, 0.79)	6.67	Moderate
Time to Stop (s)	1.90 ± 0.30	0.62 (0.41, 0.79)	4.48	Moderate
Distance to Stop (m)	7.02 ± 2.09	0.52 (0.29, 0.72)	5.73	Moderate

Note: SD = standard deviation, ICC = intraclass correlation, CI = confidence interval CV = coefficient of variation, DEC = deceleration, s = second, m = meter

Table 2 Correlation coefficients between all deceleration performance variables.

	P-DEC	P-A-V	BM	P-A-M	TTS	DTS
M-DEC (m/s^2)	.944**	-.271*	-.230*	-.354**	-0.15	.095
P-DEC (m/s^2)		-.245*	-.213	-.323**	-.231*	.072
P-A-V (m/s)			-.128	.208	-0.01	.049
BM (kg)				.926**	.037	.033
P-A-M (kg· m/s)					.023	.054
Time (s)						.599**

Note: M = mean, P = peak, Dec = deceleration, A-V = approach velocity, A-M = approach momentum,

TTS = time to stop, DTS = distance to stop, s = second, m = meter, * = $p < 0.05$, ** = $p < 0.01$

Table 3 Comparisons between greater vs. lower mean and peak deceleration performance

Grouping	Variables	Lower	Greater	Effect size (95% CI)	Magnitude
P-DEC	M-DEC (m/s^2)	2.79 ± 0.65	5.56 ± 1.46	-2.45** [-3.27, -1.63]	Very Large
	P-DEC (m/s^2)	3.40 ± 0.79	7.34 ± 1.88	-2.73** [-3.34, -2.12]	Very Large
	P-A-V (m/s)	7.30 ± 0.14	7.14 ± 0.31	0.67* [0.21, 1.12]	Moderate
	BM (kg)	71.22 ± 7.28	69.29 ± 7.90	0.25 [-0.19, 0.69]	Small
	P-A-M (kg· m/s)	519.68 ± 55.86	494.00 ± 52.16	0.48* [0.03, 0.92]	Small
	Time to stop (s)	1.95 ± 0.31	1.84 ± 0.29	0.37 [-0.08, 0.81]	Small
	Distance to stop (m)	6.57 ± 2.43	7.46 ± 1.58	-0.43* [-0.88, 0.01]	Small
M-DEC	M-DEC (m/s^2)	2.76 ± 0.62	5.59 ± 1.42	-2.58** [-3.18, -1.99]	Very Large
	P-DEC (m/s^2)	3.45 ± 0.84	7.29 ± 1.96	-2.55** [-3.14, -1.96]	Very Large
	P-A-V (m/s)	7.28 ± 0.28	7.16 ± 0.31	0.41* [-0.04, 0.85]	Small
	BM (kg)	71.88 ± 7.65	68.64 ± 7.32	0.43 [-0.01, 0.88]	Small
	P-A-M (kg· m/s)	522.81 ± 57.50	490.87 ± 48.48	0.60** [0.15, 1.05]	Moderate
	Time to stop (s)	1.94 ± 0.34	1.85 ± 0.27	0.29 [-0.15, 0.73]	Small
	Distance to stop (m)	6.55 ± 2.43	7.49 ± 1.57	-0.46* [-0.90, -0.02]	Small
A-M	M-DEC (m/s^2)	4.74 ± 1.97	3.61 ± 1.41	0.67** [0.21, 1.11]	Moderate
	P-DEC (m/s^2)	6.10 ± 2.55	4.65 ± 2.13	0.62** [0.17, 1.07]	Moderate
	P-A-V (m/s)	7.17 ± 0.32	7.27 ± 0.28	-0.33 [-0.77, 0.11]	Small
	BM (kg)	64.49 ± 5.66	76.03 ± 4.15	-2.33** [-2.89, -1.76]	Very Large
	P-A-M (kg· m/s)	461.72 ± 34.22	551.96 ± 28.84	-2.85** [-3.47, -2.23]	Very Large
	Time to stop (s)	1.86 ± 0.27	1.94 ± 0.34	-0.26 [-0.70, 0.18]	Small
	Distance to stop (m)	6.80 ± 2.12	7.24 ± 2.05	-0.21[-0.65, 0.23]	Small

P-A-V	M-DEC (m/s^2)	4.72 ±1.82	3.63 ± 1.61	0.63** [0.19, 1.08]	Moderate
	P-DEC (m/s^2)	6.08 ± 2.42	4.66 ± 2.28	0.60** [0.16, 1.05]	Moderate
	P-A-V (m/s)	6.98 ± 0.18	7.46 ± 0.18	-2.67** [-3.27, -2.06]	Very Large
	BM (kg)	70.16 ± 7.94	70.35 ± 7.37	-0.02 [-0.46, 0.41]	Trivial
	P-A-M (kg· m/s)	489.34 ± 53.50	524.34 ± 51.86	-0.66** [-1.11, -0.21]	Moderate
	Time to stop (s)	1.87 ± 0.31	1.92 ± 0.30	-0.16 [-0.60, 0.28]	Trivial
	Distance to stop (m)	7.10 ± 1.43	6.94 ± 2.60	0.08 [0.36, 0.51]	Trivial
BM	M-DEC (m/s^2)	4.06 ± 1.79	4.28 ± 1.81	-0.12 [-0.56, 0.32]	Trivial
	P-DEC (m/s^2)	5.11 ± 2.36	5.63 ± 2.53	-0.21 [-0.65, 0.23]	Small
	P-A-V (m/s)	7.25 ± 0.32	7.19 ± 0.28	0.20 [-0.24, 0.64]	Trivial
	BM (kg)	65.70 ± 5.80	74.81 ± 6.43	-1.49 ** [-1.98, 0.99]	Very Large
	P-A-M (kg· m/s)	475.90 ± 38.97	537.78 ± 51.93	-1.35 ** [-1.83, 0.86]	Very Large
	Time to stop (s)	1.88 ± 0.33	1.91 ± 0.28	-0.10 [-0.54, 0.34]	Trivial
	Distance to stop (m)	6.75 ± 2.23	7.28 ± 1.92	-0.25 [-0.69, 0.19]	Small

Note: CI = confidence interval, M = mean, P = peak, Dec = deceleration, A-V = approach velocity, A-M = approach momentum,

BM = body mass, s = second, m = meter, ** $p < 0.01$, * $p < 0.05$

Table 4. Unstandardized and standardized Beta values for each regression models

Assessment	Variable	B	t	*p*	ß
Mean deceleration	Constant	25.543	5.112	< 0.001	
	Approach velocity	-2.066	-3.391	0.001	-0.347
	Body mass	-0.092	-3.821	< 0.001	-0.391
Peak deceleration	Constant	31.297	4.454	<0.001	
	Approach velocity	-2.523	-2.945	0.004	-0.310
	Body mass	-0.110	-3.246	0.002	-0.342