Effect of sprint approach velocity and distance on deceleration performance in NCAA Division I female softball athletes

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ABSTRACT

Team sports require athletes to rapidly reduce whole body momentum and velocity, to efficiently change direction, or to avoid defenders. Decelerations often occur following varying approach distances and velocities. The aim of this study was to investigate the effects of different sprinting approach distances, and therefore velocities and momenta on measures of horizontal deceleration performance within female NCAA Division I softball players. Athletes performed an acceleration:deceleration assessment (ADA) over 20 yards (18.29 m) (ADA_{20}) and 10 yards (9.14 m) (ADA_{10}), respectively. The sample was divided into high and low performance groups for approach velocity and approach momentum, and between-group differences were studied for each test. Correlations between measures of deceleration were analysed between the ADA_{10} and ADA_{20}. Results suggested that during the ADA_{20} trials, athletes initiated the deceleration phase at greater approach velocities ($p < .001$, ES = 2.71) and momenta ($p < .001$, ES = 2.65), generating greater reductions in velocity ($p < .001$, ES = 1.60) and momentum ($p < .001$, ES = 1.50). Within the ADA_{10}, athletes within the high velocity group saw significantly greater reductions in velocity ($p = .009$, ES = 1.24). This was not observed within the ADA_{20}. A significant negative association was found between average deceleration within the ADA_{10} and ADA_{20} (r = -0.443, $p = .039$). Findings suggest that horizontal decelerations are influenced by the approach distance, velocity, and momentum, which athletes are exposed to before initiating the deceleration phase. This should be accounted for when implementing training to enhance such qualities.

Keywords: Biomechanics; Deceleration; Softball; Sprint.

Cite this article as:
Philipp, N. M., Blackburn, S. D., Cabarkapa, D., & Fry, A. C. (2023). Effect of sprint approach velocity and distance on deceleration performance in NCAA Division I female softball athletes. *Journal of Human Sport and Exercise, 18*(3), 542-554. https://doi.org/10.14198/jhse.2023.183.03

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Submitted for publication January 07, 2023.
Accepted for publication February 08, 2023.
Published July 01, 2023 *(in press* February 21, 2023).
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202.

doi:10.14198/jhse.2023.183.03

INTRODUCTION

The majority of team, court or field-based sports require athletes to rapidly decelerate their centre of mass (COM), for example in response to other players' movements by avoiding collisions, evading defenders, or putting them in a better position to score while staying within the dimensions of the playing field (Harper et al., 2019; Hewit et al., 2011). These rapid deceleration actions are often preceded by varying running velocities and approach distances (Hewit et al., 2011). From a physical standpoint, maximal horizontal decelerations require athletes to generate large braking forces over short ground contact times, in order to effectively reduce whole body momentum (mass x velocity) (Dos'Santos, Thomas, Jones & Comfort, 2017). According to Harper et al., a larger magnitude of braking force during the deceleration may reduce the time needed to generate the requisite impulse to reduce momentum, enabling athletes to achieve a more efficient deceleration (Harper et al., 2022). While still limited, previously, researchers have tried to establish relationships between other markers of physical fitness and maximal horizontal deceleration or change of direction performance. For instance, concentric peak torque measured at higher knee joint angular velocities, in addition to selected countermovement jump and drop jump metrics were found to have significant associations with measures of horizontal deceleration performance (Harper, Jordan & Kiely, 2021; Harper et al., 2020; Harper et al., 2022). Further, Spiteri et al (2014), have reported eccentric strength to be an important contributor of change of direction performance within female basketball athletes. Furthering this thought of the importance of eccentric strength with regards to change of direction ability, other authors have proposed similar findings (Jones et al., 2017; Jones et al., 2022).

The majority of the novel literature looking at horizontal deceleration performance has used the acceleration-deceleration-assessment (ADA) as the tool to gain insights into athletes' deceleration capabilities (Harper et al., 2019). This test requires athletes to perform a maximal sprint acceleration (generally over 20 meters), followed by a rapid horizontal deceleration. Interestingly, mixed findings have previously been reported with regards to the impact of approach velocity on different measures of deceleration performance. Fernandes et al. have suggested that athletes with a higher change of direction deficit (poorer change of direction ability) showed greater linear acceleration, and a greater approach momentum coming into the deceleration, and ultimately the change in direction (Fernandes et al., 2021). The change of direction deficit is a novel means of quantifying change of direction performance by accounting for an athlete's linear speed ability (Nimphius et al., 2016). Building upon that notion, both Freitas et al., as well as Loturco et al., reported larger change of direction deficits in groups of faster athletes, suggesting that carrying a greater velocity into the deceleration may challenge athletes to a greater degree when it comes to decreasing their own momentum (Freitas et al., 2018; Loturco et al., 2019). Fernandes et al. suggested that therefore, faster athletes must exert greater impulses to decelerate, which makes them more likely to require longer ground contact times (Fernandes et al., 2021). Other research has shown the deceleration phase prior to changes in direction to be angle-specific, with slower velocities and longer deceleration distances, preceding 90-degree cuts, compared to 45-degree cuts (Havens and Sigward, 2014; Hader et al., 2015; Hader et al., 2016). On the other hand, other research has suggested that greater acceleration and sprint speeds preceding the deceleration phase have been shown to lead to a greater ability for athletes to rapidly reduce their velocity or reduce their velocity followed by a change in direction. In a recent study, Baena-Raya el. showed that greater horizontal sprint mechanical properties (e.g., theoretical maximal horizontal force, maximal horizontal power output) were significantly associated with lower change of direction deficits within a population of male and female basketball players. Beyond that, greater approach velocities within the ADA test have been shown to differentiate high from low horizontal deceleration performers, opposing what has been found within a lot of the literature previously mentioned, looking at the change of direction deficit (Harper et al., 2022; Harper et al., 2020). At this point it seems difficult to conclude whether or not approach velocity has a positive or a negative impact on horizontal deceleration performance, given that the ADA test requires athletes to decelerate without a following rapid change in direction. The majority of the literature investigating the change of direction deficit has done so utilizing the 5-0-5 change of direction test, which requires athletes to perform a 180-degree turn following a linear sprint acceleration. Future research should investigate differences in horizontal deceleration profiles in tests that do and do not include a change in direction and re-acceleration, following the horizontal deceleration. Further, there is a lack of literature, focused on investigating horizontal deceleration performance in highly trained female populations. Female athletic populations tend to be more susceptible toward injuries to the anterior cruciate ligament, which often occur during movement patterns that involve rapid stopping, cutting, and changing direction (Ireland, 2022). A more thorough understanding of deceleration mechanics and potential ways to train for such qualities in female populations may also help contribute to an existing body of literature. Therefore, the purpose of the present study was to investigate the effects of approach velocity, approach momentum, and approach distance on subsequent measures of maximal horizontal deceleration performance within a sample of division I female athletes. While largely related, the aims of this study were threefold. Aim one was to investigate differences and correlations between metrics of interest for the two versions of the ADA (i.e., ADA_{10} and ADA_{20}). Aim two was to investigate differences between high and low performance groups with regards to approach velocity, and approach momentum for the two ADA assessments, respectively. We hypothesized that performance would likely differ between the two assessments, based on approach distances and velocities prior to initiating the deceleration phase, and that based on this information practitioners may further individualize their approach towards deceleration training.

METHODS

Subjects

The sample for this investigation included 22 NCAA division I female softball players (age = 19.8 ± 1.5 years, mass = 74.2 ± 12.9 kg, height = 1.72 ± 0.06 m) competing at a power 5 University within the United States. All participants were cleared to participate by the sports medicine staff and were free of musculoskeletal injuries. All testing procedures were approved by the University's Institutional Review Board and all subjects signed an informed consent form prior to participation. Procedures for the 10-yard (9.14 m) ADA test were performed one week after procedures for the 20-yard (18.29 m) ADA test.

Maximal horizontal deceleration test

Procedures to assess athletes' maximal horizontal deceleration qualities were adapted from the previous literature (Harper et al., 2020). Athletes performed three trials of the horizontal acceleration-deceleration ability (ADA) test with a 20-yard (18.29 m) approach (ADA_{20}), and the following week with a 10-yard (9.14 m) approach (ADA_{10}). This test has been shown to be reliable and sensitive to detecting kinetic deceleration metrics (e.g., average horizontal deceleration, horizontal braking impulse) (Harper et al., 2020). Athletes started in a staggered two-point stance, 30 centimetres behind one set of timing gates (Brower Timing Systems, Draper, USA), prior to commencement of the sprint. From there, athletes accelerated maximally over 10 (9.14 m), and 20 (18.29 m) yards, respectively, and performed a maximal horizontal deceleration immediately after crossing the 10 (9.14 m), and 20 (18.29 m) yard mark. The other set of timing gates was placed at the 10 (9.14 m), and 20 (18.29 m) yard mark, respectively. Athletes were instructed to initiate the deceleration as close to the 10 (9.14m)-, and 20 (18.29m)-yard mark as possible, and to not initiate the deceleration prior to crossing the mark. To ensure this, athletes' trials were not counted, and athletes were asked to re-do their ADA trial following a two-minute passive rest period, if there was greater than a 5% difference between their 0-10 (9.14m), and 0-20 (18.29m)-yard approach time within the ADA, and the average of three linear sprint completion times over each respective distance. Linear sprint times over the two distances were recorded by the team's certified strength and conditioning coach the week prior to the first ADA testing session and were utilized for research purposes. Further, athletes were instructed to initiate their sprint acceleration without a backward or "*false*" step or "*rocking motion*", and to sprint as fast as possible through the 10 (9.14 m), and 20 (18.29 m) yard mark. Following the maximal horizontal deceleration, athletes were instructed to backpedal to the respective mark at which they initiated the deceleration to highlight a clear change in instantaneous velocity, signifying the end of the deceleration phase. Each athlete performed three trials, with the average of the three trials used for further analyses. All trials were performed on an indoor artificial turf surface.

Similar to previous research (Harper et al., 2020; Simperingham et al., 2016), instantaneous horizontal velocity was recorded throughout the entire ADA test using a radar device (Stalker ATS II, Applied Concepts, Inc., Dallas, TX, USA) sampling at a frequency of 47 Hz. The tripod-mounter radar device was placed 5 meters behind the start line, which was in line with the manufacturer's recommendations for measuring acceleration and deceleration trials. The target direction on the radar was set to 'both', to enable the device to record movement going away and towards the radar. Lastly, the radar was placed on the tripod at a height that was in line with each respective athlete's centre of mass.

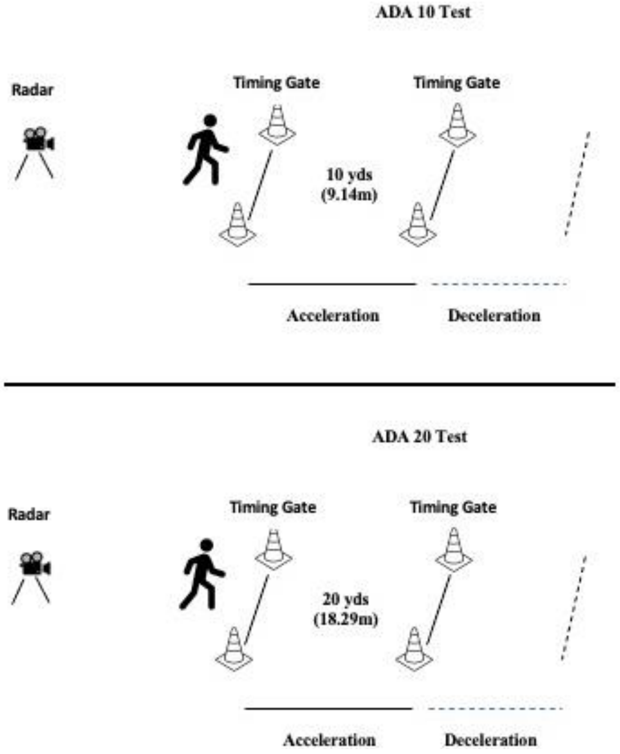


Figure 1. Visual Representation of the ADA Test.

Radar data analysis

The raw and instantaneous horizontal velocity data provided by the radar was manually processed using the device's own software program (Version 5.0, Applied Concepts, Inc., Dallas, Texas, USA), as suggested by Simperingham et al. (2016). Following this procedure, data were exported into the RStudio software (Version 1.4.1106) for further analysis. In line with suggestions by Harper et al. (2020), the start of the deceleration phase was defined as the time point immediately following peak velocity (Vmax), while the end of the deceleration phase was defined as the lowest velocity (Vlow) following Vmax (Harper et al., 2020).

Additionally, the deceleration phase was divided into an early, and a late deceleration phase, using 50% of peak velocity as the cut-off point between early and late phases. Similar to previous literature, maximal horizontal deceleration performance was analysed using several different metrics: average horizontal deceleration (HDEC), average horizontal braking impulse (HBI), and time to stop (TTS). These metrics were calculated from velocity and time data points captured between the start and the end of the deceleration phase, and detailed calculations may be found elsewhere (Harper et al., 2020; Philipp et al., 2022). Lasty, one additional ratio metric was calculated to gain further insights into horizontal deceleration strategies. The Early:Late Deceleration Ratio (Early:Late DEC Ratio) was calculated by dividing the early HDEC ($HDEC_e$) by the late HDEC ($HDEC_l$). 50% of maximal velocity during the ADA trial was used to distinguish between the early and late deceleration phase. Most horizontal deceleration metrics used within this study have previously been found to be reliable (Harper et al., 2022; Harper et al., 2020). In this study, the coefficient of variation (CV%) for all radar metrics ranged from 3.01–11.46. All deceleration metrics and respective equations are reported in Table 1.

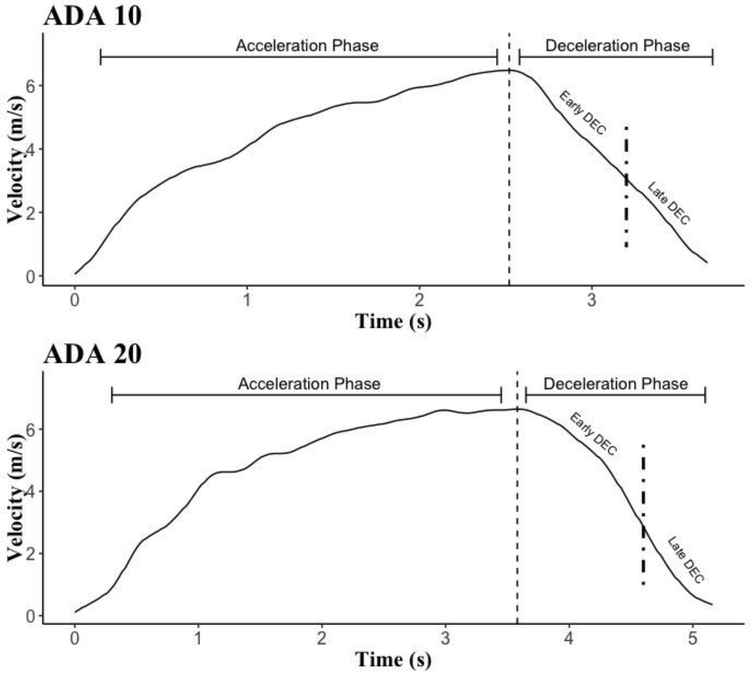
Statistical analysis

All data were assessed for normality using the Shapiro-Wilk statistics, and within-session coefficients of variation (CV) were calculated for all maximal horizontal deceleration metrics. Paired sample, student's (parametric data), and Wilcoxon rank (non-parametric data) t-tests were performed to investigate differences in ADA test metrics between the ADA_{10}, and the ADA_{20} trials. Similar to other studies (Fernandes et al., 2021; Freitas et al., 2018; Loturco et al., 2019), athletes were divided into high and low performance groups, utilizing a median split analysis for maximal approach velocity, and maximal approach momentum, separately. Student's (parametric data) and Mann-Whitney U (non-parametric data) independent sample's t-tests were used to investigate differences in horizontal deceleration characteristics for the ADA_{10}, and ADA_{20} tests, and between groups of high and low performers. To evaluate the group-specific magnitude of difference for all metrics of interest, Cohen's D effect sizes (ES) were calculated. Cohen's d ES's were classified as either trivial (<0.20), small (0.20-0.49), moderate (0.50-0.79), or large (>0.80) (Cohen, 1977). Pearson's (parametric data), and Spearman's (non-parametric) correlation coefficients were calculated between horizontal deceleration metrics for the ADA_{10}, and the ADA_{20} test to investigate the relationships between the two assessments, and to determine whether or not the two tests provide similar estimations of horizontal deceleration performance for each athlete. To compare relative deceleration performance for each athlete, and to visualize potential discrepancies between deceleration metrics from the ADA_{10} and ADA_{10}, normalized z-scores for all metrics of interest were calculated using the following calculation: *Z-score = (Athlete's test score – sample mean score) / SD*. Coefficients of variation (CV) were calculated for all metrics using the following equation: *CV = (athlete score SD) / (athlete mean score) * 100* (Nimphius et al., 2016). Statistical inferences were made using an alpha level of $p \leq .05$. All data were analysed and visualized using the RStudio Software (Version 1.4.1106), as well as the R statistical computing environment and language (v. 4.0; R Core Team, 2020) via the Jamovi graphical user interface.

Table 1. Explanation of horizontal deceleration metrics examined in the present study.

Horizontal deceleration metrics (unit)	**Definition – Equation**
Max Approach Velocity ($m \cdot s^{-1}$)	Maximal velocity achieved prior to deceleration
Max Approach Momentum ($kg \cdot m \cdot s^{-1}$)	Maximal momentum achieved prior to deceleration
Average horizontal deceleration ($m \cdot s^{-2}$)	Change in velocity over time - (Vf–Vi)/(Tf–Ti)
Time to stop (s)	Time from start to end of deceleration phase - Tf–Ti
Horizontal braking impulse (N·s)	Change in momentum over time - Mf–Mi
Early:Late Deceleration Ratio (Ratio)	Ratio between the average early and late deceleration values

*Note: V_f = final velocity, V_i = initial velocity, T_f = final time, T_i = initial time, momentum = mass * velocity, M_f = final momentum, M_i = initial momentum, BM = body mass.*



Note: Example representation of a velocity-time plot for each respective version of the ADA, for a random athlete from the sample. Represented on each plot are the acceleration phase, the deceleration phase, as well as the early and the late deceleration phase (cut-off point = 50% of max velocity)

Figure 2. Example visual representation of horizontal instantaneous velocity during the ADA_{10} and ADA_{20} tests from random athletes.

RESULTS

Differences and Correlations in ADA test metrics between the ADA_{10}, and ADA_{20} trials

Descriptive statistics (mean ± SD), and between group Cohen's D effect sizes can be seen in Table 2. CV%'s for all metrics within the two assessments ranged from 3% - 12% and were therefore deemed reliable. Within the ADA_{20} tests, athletes experienced significantly greater approach velocities (p = < .001, ES = -2,71), approach momentum (p = < .001, ES = -2.65), HDEC values (p = < .001, ES = 1.60), and HBI values (p = < .001, ES = 1.51), while in the ADA_{10} tests, athletes showed significantly shorter TTS values (p = .003, ES = -0.73). No significant differences were found between Early:Late DEC Ratios.

Table 2. Differences and correlations in ADA test metrics between the ADA_{10}, and ADA_{20} trials.

Variable	**Comparison**				**Correlation**	
	ADA_{10}	ADA_{20}	*p*-value	ES	Coefficient	*p*-value
Max Approach Velocity	6.20 ± 0.35	7.06 ± 0.36	**<.001**	2.71	0.598	**.003**
Max Approach Momentum	457.01 ± 71.95	521.14 ± 82.78	**<.001**	2.65	0.961	**<.001**
HDEC	-3.26 ± 0.30	-4.16 ± 0.36	**<.001**	1.60	-0.443	**.039**
HBI	-411.12 ± 60.41	473.16 ± 84.93	**<.001**	1.50	0.832	**<.001**
TTS	1.46 ± 0.16	1.70 ± 0.36	**.003**	0.73	0.375	.086
Early:Late DEC Ratio	0.30 ± 0.05	0.31 ± 0.06	.573	0.12	0.205	.360

Note: DEC = Deceleration, ACC = Acceleration. HDEC = Average Horizontal Deceleration, HBI = Average Horizontal Braking Impulse, TTS = Time to Stop, DEC = Deceleration. Bold text denotes statistically significant differences or correlations between groups.

Results from the correlation analysis between horizontal deceleration performance metrics for the two versions of the ADA test revealed significant associations between HDEC$_{10}$ and HDEC$_{20}$ (r = -0.443, *p* = .039), HBI$_{10}$ and HBI$_{20}$ (r = 0.893, *p* = < .001). Further correlations between ADA$_{10}$ and ADA$_{20}$ deceleration variables may be viewed in Table 5, while Figure 3 highlights individual athlete comparisons for HDEC performance within the ADA$_{10}$ and ADA$_{20}$.

Differences in horizontal deceleration metrics between high and low performance groups for maximal approach velocity and maximal approach momentum

Table 3. Differences in horizontal deceleration metrics between high and low performance groups for maximal approach velocity and maximal approach momentum within the ADA$_{10}$ trial.

Variable	**High Velocity$_{10}$**	**Low Velocity$_{10}$**	***p*-value**	**ES**
Height	1.70 ± 0.04	1.73 ± 0.07	.266	0.49
Weight	69.37 ± 11.12	78.66 ± 13.49	.093	0.75
HDEC	-3.42 ± 0.25	-3.11 ± 0.26	**.009**	1.24
HBI	-405.31 ± 50.63	-416.92 ± 70.89	.663	-0.19
TTS	1.41 ± 0.12	1.51 ± 0.19	.167	0.61
Early:Late DEC Ratio	0.30 ± 0.05	0.30 ± 0.05	.976	-0.01
Variable	**High Momentum$_{10}$**	**Low Momentum$_{10}$**	***p*-value**	**ES**
Height	1.72 ± 0.08	1.71 ± 0.04	.537	0.27
Weight	82.40 ± 13.28	65.63 ± 4.69	**<.001**	1.68
HDEC	-3.26 ± 0.27	-3.27 ± 0.34	.912	0.05
HBI	-453.82 ± 56.32	-368.41 ± 21.87	**<.001**	2.00
TTS	1.45 ± 0.14	1.48 ± 0.19	.677	0.18
Early:Late DEC Ratio	0.30 ± 0.05	0.30 ± 0.05	.983	0.01

Note: DEC = Deceleration. HDEC = Average Horizontal Deceleration, HBI = Average Horizontal Braking Impulse, TTS = Time to Stop, DEC = Deceleration. Bold text denotes statistically significant differences between groups.

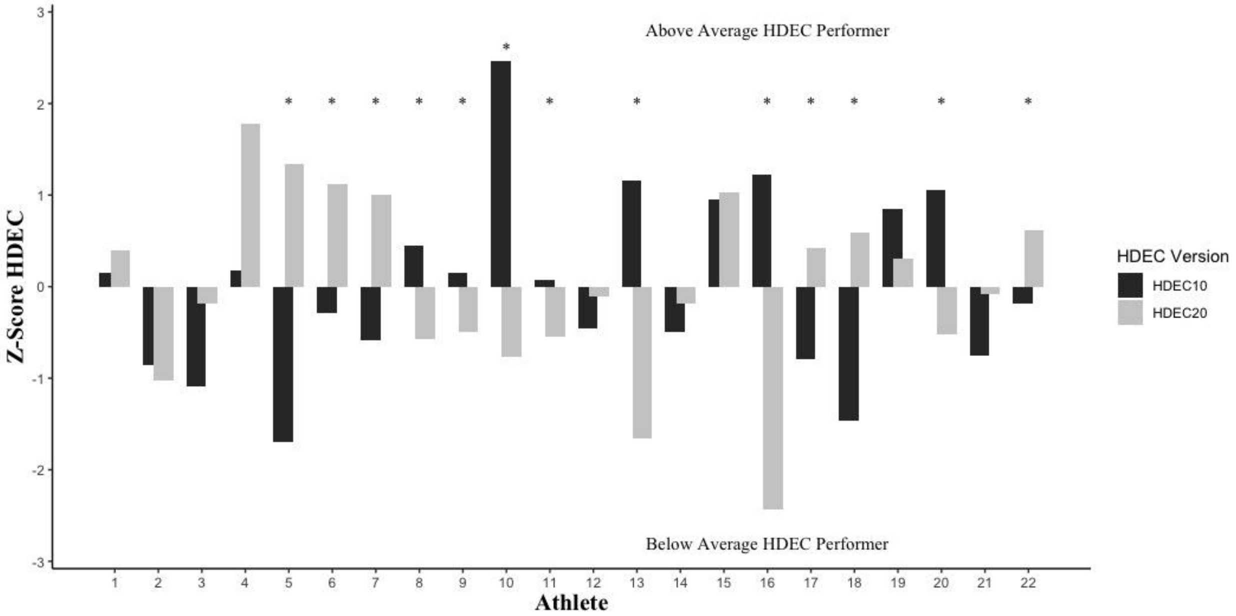
Table 4. Differences in horizontal deceleration metrics between high and low performance groups for maximal approach velocity and maximal approach momentum within the ADA$_{20}$ trial.

Variable	**High Velocity$_{20}$**	**Low Velocity$_{20}$**	***p*-value**	**ES**
Height	1.71 ± 0.04	1.73 ± 0.08	.448	0.33
Weight	69.37 ± 11.12	78.66 ± 13.49	.202	0.56
HDEC	-4.21 ± 0.33	-4.12 ± 0.26	.551	0.23
HBI	-472.79 ± 81.32	-473.54 ± 92.48	.984	0.01
TTS	1.72 ± 0.40	1.69 ± 0.32	.867	0.07
Early:Late DEC Ratio	0.29 ± 0.03	0.33 ± 0.07	.102	0.73
Variable	**High Momentum$_{20}$**	**Low Momentum$_{20}$**	***p*-value**	**ES**
Height	1.72 ± 0.08	1.71 ± 0.04	.536	0.27
Weight	82.40 ± 13.28	65.63 ± 4.69	**<.001**	1.68
HDEC	-4.21 ± 0.41	-4.12 ± 0.32	.583	0.24
HBI	-532.17 ± 79.93	-414.15 ± 33.41	**<.001**	1.93
TTS	1.75 ± 0.32	1.66 ± 0.40	.568	0.25
Early:Late DEC Ratio	0.30 ± 0.06	0.32 ± 0.05	.345	0.41

Note: DEC = Deceleration. HDEC = Average Horizontal Deceleration, HBI = Average Horizontal Braking Impulse, TTS = Time to Stop, DEC = Deceleration. Bold text denotes statistically significant differences between groups.

During the ADA$_{10}$, HDEC revealed the only significant difference between groups, accompanied by a large effect size (*p* = .009, ES = 1.24), with athletes possessing a larger approach velocity being able to reduce their velocity more rapidly (see Table 3). Looking at approach momentum, significant between group differences were observed for HBI (*p* = < .001, ES = 2.00), with athletes in the high approach momentum group having a higher braking impulse.

Within the ADA$_{20}$, no significant differences were found between high and low velocity groups (see Table 4). However, the Early:Late DEC Ratio was approaching a large effect size (*p* = .102, ES = 0.74), indicating that athletes in the high velocity group experienced less balance in velocity reduction during the two phases.



Note: The "" indicates cases where athletes HDEC value was above average for one version of the ADA, and below average for the other version of the ADA*

Figure 3. Z-scores for HDEC Performance between the ADA$_{10}$ and ADA$_{20}$.

DISCUSSION

The aim of the present study was to investigate the effects of approach velocity, approach momentum, and approach distance on subsequent measures of maximal horizontal deceleration performance within a sample of NCAA division I female athletes. To do so, differences and associations between ADA test trials over the two different distances were investigated. Further, groups of high and low performers with regards to approach velocity and momentum were compared for each version of the ADA. As expected, and in line with our hypothesis, during the ADA$_{20}$ trials athletes initiated the deceleration phase at greater approach velocities and momenta, generating greater reductions in velocity (HDEC) and momentum (HBI). These findings alone may provide evidence that horizontal deceleration exposure likely depends on the sport, and the dimensions in which the sport is being played in, encouraging practitioners to implement training and assessment tools to prepare athletes for the deceleration actions experienced most commonly in their sport.

When dividing the sample into high and low velocity, as well as momentum groups, for each respective version of the ADA test, between group comparisons revealed that for the ADA$_{10}$ athletes with a higher approach velocity were able to generate significantly larger reductions in speed (ES = 1.24). Further, athletes in the high momentum group were significantly heavier (ES = 1.68), and experienced greater reductions in horizontal momentum (ES = 2.00), shown by greater HBI values. For one, these findings are in line with research suggesting that initiating the deceleration phase at greater approach velocities, allows for an "*opportunity*" to attain higher rates of horizontal deceleration (Harper et al., 2022; Newans et al., 2019; Oliva-Lozano et al., 2020). Further, it shows that greater approach momenta require athletes to generate a larger horizontal braking impulse. While somewhat speculative, if a high approach momentum is not accompanied by sufficient levels of strength or momentum reduction strategies, levels of injury risk may be elevated (Harper & Kiely, 2018).

Within the ADA_{20} test, interestingly, this "*opportunity*" to attain larger reductions in horizontal velocity, following a greater approach velocity did not hold up (ES = 0.23), suggesting again that horizontal deceleration performance may be task-, or approach distance-specific. Furthermore, during this version of the ADA test, a moderate to large effect size was found showing that athletes with a larger approach velocity had a smaller Early:Late DEC Ratio (ES = 0.73). This suggests that faster athletes experienced a larger discrepancy between their early and late deceleration phases, attaining larger reductions in horizontal velocity during the late compared to the early deceleration phase. This finding may offer insights with regards to the individualization of training for deceleration performance. Athletes within the high approach velocity group may benefit from interventions enabling them to generate larger reductions in horizontal velocity during the early deceleration phase, increasing their Early:Late DEC Ratio. Harper et al. has recently shown associations between metrics such as reactive strength index and concentric mean force, extracted from a drop jump assessment to be related to performance within the early horizontal deceleration phase of the ADA_{20} test. Further, Jones et al. has proposed that greater eccentric quadriceps strength may allow athletes to attain greater reductions in speed during the preparatory steps of a rapid change of direction manoeuvre. While limited in existing evidence, implementing training strategies that enable athletes to improve their "*stretch-load*" capacity of the muscle-tendon unit during short (<0.25s), high force impacts, may potentially carry over to horizontal deceleration performance (Young, 1995). Previous research has suggested that athletes with greater drop jump reactive strength performance seem better able to generate larger eccentric braking forces under increased eccentric loading demands. This physical capacity may be of importance, given that similar to the ADA_{10}, within the ADA_{20} athletes within the high approach momentum group were significantly heavier in weight (ES = 1.68), and experienced significantly larger reductions in horizontal momentum (ES = 2.00). While the previously mentioned might be helpful with regards to training strategies to improve early deceleration phase performance, the general idea behind the somewhat skewed Early:Late DEC Ratio in favour of a higher later deceleration phase performance may lie within the nature of the sport population that was investigated within this study. Previous research has proposed the idea of a "*preparatory*" braking period, during which athletes go through postural adjustments and a more gradual reduction in velocity, prior to a faster braking period that consists of a higher posteriorly directed braking force and a more rapid reduction in velocity (Harper et al., 2022; Jian et al., 1993). It is reasonable to speculate that softball players employ such a "*preparatory*" braking strategy in order to efficiently round the bases during game play. Beyond that, compared to other sports, for softball players it is rarer to experience rapid horizontal reductions.

When examining relationships between ADA_{10} and ADA_{20} deceleration metrics, significant associations were identified between HBI_{10} and HBI_{20} (r = 0.832, p = < .001), and $HDEC_{10}$ and $HDEC_{20}$ (r = -0.443, p = .039). Interestingly, for HDEC, the direction of the relationship is flipped, suggesting that those athletes with greater HDEC performance within the ADA_{10} performed relatively worse with regards to HDEC in the ADA_{20}. This finding may add further evidence to the suggestion that deceleration performance is likely dependent on the approach distance and velocity, and that it is somewhat uncertain whether or not a greater approach velocity makes for a greater "*opportunity*" to attain higher rates of deceleration, as previously suggested (Harper et al., 2022; Harper et al., 2020; Newans et al., 2019; Olivia-Lozano et al., 2020). As seen in Figure 2, 13 out of 22 athletes were shown to be above average HDEC performers within one version of the ADA, and below average within the other version of the ADA, indicating that different physical qualities may be required to rapidly and efficiently reduce velocity following differing approach distances and velocities. In sports where competition field of play dimensions allow athletes to frequently perform maximal horizontal decelerations following different approach distances and velocities (e.g., soccer, American football, rugby), practitioners may use information such as Figure 2 to individually prescribe training based on proficiency.

Within the realms of sprint training and research, it is common to individualize training based on proficiency within different phases of the sprint (e.g., acceleration vs. top end speed). While novel and speculative, based on findings from within this study, horizontal deceleration training may be individualized based on approach velocity and distance. For instance, athlete 16 is shown to be an above average performer within the ADA_{10} however, performs well below average within the ADA_{20}. This finding may inform a practitioner to implement a training strategy to aid athlete 16 to more effectively reduce velocity following a longer approach distance, likely consisting of a greater approach velocity, and greater degrees of approach momentum. These suggestions should be solidified through further research looking at other athlete populations, as well as potentially other horizontal deceleration tasks. Additionally, future research should aim to quantify the effects of a change in direction in horizontal deceleration performance, using similar methodologies to the ones used in this study. Deceleration mechanics will likely differ when athletes rapidly reduce velocity to come to a stop, compared to when they are required to change direction and re-accelerate following the deceleration.

While we believe our study adds to the body of literature investigating physical performance within highly trained female athletes, results must be interpreted with caution, given that results may look different based on gender, training age, or sport participation. Our results have shown that horizontal deceleration performance may be dependent on the approach distance and velocity, which is likely influence by the nature and physical dimensions of a given sport or playing field.

CONCLUSION

Findings from our study demonstrate that maximal horizontal deceleration performance is likely influenced by the approach distance, velocity, and momentum that athletes generate prior to initiating the deceleration phase. During the ADA_{20} athletes experienced significantly greater approach velocities and momenta, as well as greater average horizontal decelerations and greater horizontal braking impulses. Within the $ADA_{10,}$ faster athletes were able to generate greater reductions in velocity throughout the deceleration phase, while for the ADA_{20}, HDEC performance was similar between the high and low approach velocity groups. The correlation analysis has further solidified these discrepancies with regards to athletes' ability to rapidly reduce their velocity. This further shows that physical qualities underpinning horizontal deceleration performance for tasks following greater approach distances and velocities likely require an additional emphasis in training, such as strength training, plyometrics, or skill-specific exercises. Practitioners may use results identified in this study to further individualize their approach towards improving such physical qualities, influencing deceleration proficiency. However, further research is warranted to establish training modalities positively affecting different kinds of deceleration tasks.

AUTHOR CONTRIBUTIONS

All co-authors have contributed to the published work and agree to its publication in JHSE.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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