KINEMATIC DIFFERENCES BETWEEN SPRINTING AND THE HURDLE JUMP EXERCISE – A PRELIMINARY ANALYSIS

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The hurdle jump is a commonly prescribed plyometric exercise for sprint athletes. The purpose of this study was to assess the lower body kinematic differences between maximal velocity sprinting and hurdle jumps performed over a range hurdle heights. Six competitive male sprinters performed maximum effort sprints over 50 m and hurdle jumps over 0.60, 0.75 and 0.90 m. Ground contact times, ankle, knee, and hip angles were collected during the ground contact phase of all trials. Significantly lower peak dorsiflexion angles and lower mean ground contact times were found in sprinting compared to all three hurdle jump conditions (all $p < 0.015$). The hurdle jump exercise may be a suitable exercise for sprint athletes due to the greater demand imposed on the athlete relative to maximum velocity sprinting. Coaches are advised to monitor ground contact times to ensure the intensity of the exercise is not excessive.

KEYWORDS: contact time, plyometrics, maximum velocity.

INTRODUCTION: Recent research has found that the hurdle jump is the most widely prescribed resistance training exercise for sprinters and is considered the most important plyometric exercise by Irish sprint coaches (Healy et al., 2019). Coaches can alter the training stimulus provided by the hurdle jump by increasing the height of the hurdles or increasing the number of hurdles used. Hurdle heights between 0.3 and 0.9 m high are typically recommended with higher heights ~1 m also used (Cappa & Behm, 2011). Previous biomechanical investigations have focused on the effects of changing hurdle height and increasing the preceding drop height on hurdle jump performance (Song et al., 2010, Cappa & Behm, 2011). Cappa & Behm (2011) reported that, in a sample of Rugby players, increasing hurdle height significantly increases ground contact time, reduces the peak vertical ground reaction force and rate of force development.

Hurdle jumps have been recommended as a suitable exercise for maximum velocity sprinting and the development of reactive ability (Young et al., 2001; Wild et al., 2011). However, inconsistent results have been reported in interventions carried out in sprint athletes utilising hurdle jumps. Satkunskiene et al. (2009) reported no significant difference in maximum velocity and step kinematics over 40 m after 8 weeks of power training in male sprinters. In contrast, Kamandulis et al. (2012) reported a 1.8% improvement in sprint time over 60 m following four weeks of power training in national male level sprinters. Consequently, a direct comparison between the hurdle jump exercise and maximal velocity sprinting is warranted. Thus, the aim of this study was to assess the lower body stance phase kinematic differences in male sprinters between maximal velocity sprinting and hurdle jumps performed over a range of commonly used and prescribed hurdle heights: 0.60, 0.75, and 0.90 m.

METHODS: Data Capture: Six male collegiate sprinters (mean ± SD, age: 22 ± 4 years; body mass: 75.3 ± 7.4 kg; height: 1.80 ± 0.05 m) were recruited for this study. Testing took place over two separate days. On day one, sprinters performed three maximal effort 50 m sprints on an indoor sprint track with six minutes of recovery time provided between sprints. The capture volume was positioned at the 37.5 – 45 m zone of the 50 m sprint similar to previous work (Bezodis et al. 2008). Maximum velocity was calculated as the distance covered (7.5 m) divided by the time taken which was recorded using two Racetime 2, dual-beam timing gates (Microgate, Bolzano, Italy) positioned at either end of the capture volume. On day two, sprinters performed three repetitions of hurdle jumps over 0.60 m, 0.75 m and 0.90 m in an indoor biomechanics laboratory. For each trial, four hurdles were evenly spaced 1 m apart. Kinematic data were captured only for the ground contact phase of the landing of the second hurdle jump, similar to previous investigations (Cappa & Behm, 2011). One-minute rest was provided after each trial and three minutes rest was provided after each hurdle jump height to mitigate the effects of fatigue (Cappa and Behm 2011). Subjects were instructed to clear all hurdles while spending as little time as possible on the ground (Cappa and Behm 2011). The subjects' arm movement was not restricted so that the hurdle jumps were performed as they would be in training (Cappa & Behm, 2011).

Thirty-two 12.7 mm retro-reflective spherical markers were attached to each sprinter on the ASIS, PSIS, medial and lateral epicondyle, medial and lateral malleolus, 1st and 5th metatarsal, on the athlete's own spiked shoes, on both right and left sides. Marker clusters, consisting of four markers, were placed on the right and left thigh and shank. An initial static calibration trial was performed during each testing session to establish joint centres, segment lengths and to define each segment's local coordinate system. The medial epicondyle and malleolus on the right and left sides were removed after a successful static trial. Sprint and hurdle jump kinematic data were captured using an eleven (six Eagle and five Hawk) camera MAC system (Motion Analysis Corporation, Santa Rosa, CA, USA) operating at 200 Hz.

Data Processing: Marker trajectories were digitised and exported using Cortex Motion Analysis Software (version 6.0; Motion Analysis Corporation, Santa Rosa, CA, USA). For all trials, the ground contact phase of the right leg was identified as the first and last peak vertical acceleration of the fifth metatarsal marker which corresponded to touchdown and take-off respectively (Hreljac & Marshall 2000). Contact time was calculated as the elapsed time between touchdown and take-off. A seven-segment model consisting of the pelvis, right and left thigh, shank and foot was created using marker coordinate data and scaled using the sprinter's segment lengths, height, and body mass in Visual 3D (C-Motion, Rockville, MD, USA). Angle rotation around the x-axis i.e. flexion / extension or dorsiflexion / plantar flexion was calculated for the ankle, foot coordinate system around the shank coordinate system, the knee, shank coordinate system around the thigh coordinate system, and the hip, thigh coordinate system rotation around the pelvis coordinate system. The static standing trial was used as a reference point for all angles representing neutral or 0° flexion / extension and dorsiflexion / plantar flexion similar to previous investigations (Stefanyshyn & Nigg 1998). Positive angles represented extension / plantar flexion whereas negative angles represented flexion / dorsiflexion relative to the static trial. The angle at touchdown and take-off was retained for the ankle, knee and hip and the peak flexion / dorsiflexion angle was retained for the ankle and knee. All recorded kinematic data were filtered using a fourth-order Butterworth Low-Pass filter with an optimal cut-off frequency of 12 Hz determined via residual analysis.

Statistical Analysis: Descriptive statistics were presented as mean ± SD. Due to the small sample size, differences were calculated between sprinting and the individual hurdle jump conditions only. Kinematic differences between sprint and hurdle jumps were assessed using paired samples t-tests. All statistical analyses were performed using SPSS software (version 24.0, SPSS, Inc., IL, USA).

RESULTS: Descriptive statistics for all variables are presented in Table 1. Significantly lower peak dorsiflexion angles were found in the sprint relative to the 0.60 m hurdle jumps (mean difference ± SD = 19.6±13.2°, $p = 0.015$), 0.75 m hurdle jumps (mean difference ± SD = 24.9±7.3°, $p < 0.001$) and 0.90 m hurdle jumps (mean difference ± SD = 24.5±12.7°, $p = 0.012$). The mean sprint contact times were significantly shorter than those recorded during the 0.60 m hurdle jumps (mean difference ± SD = -0.072±0.036 s, $p = 0.004$), 0.75 m hurdle jumps (mean difference ± SD = -0.084±0.038 s, $p = 0.003$) and 0.90 m hurdle jumps (mean difference ± SD = -0.082±0.028 s, $p = 0.003$). Mean ensemble curves were generated, for graphical purposes only, and are given for the ankle, knee and hip angles for all conditions in Figure 1.

Table 1: Mean ± SD ankle, knee, and hip angles and ground contact times for the sprint and hurdle jump over 0.60, 0.75 and 0.90 m. Significant differences are highlighted with an asterisk and in bold ($p < 0.05$).

Variable	Sprint	0.60 m Hurdle Jump	0.75 m Hurdle Jump	0.90 m Hurdle Jump[1]
Ankle				
Angle at Touch Down (°)	9.1 ± 7.1	12.1 ± 10.7	7.0 ± 11.5	4.0 ± 5.0
Angle at Take-Off (°)	27.9 ± 6.4	18.5 ± 6.7	**17.6 ± 4.3***	18.1 ± 8.4
Peak Dorsiflexion Angle (°)	-19.3 ± 4.8	**-38.9 ± 9.1***	**-44.2 ± 5.6***	**-43.8 ± 9.5***
Knee				
Angle at Touch Down (°)	-30.5 ± 7.3	-26.5 ± 9.2	-30.3 ± 7.1	-31.3 ± 8.7
Angle at Take-Off (°)	-22.4 ± 9.1	-16.5 ± 10.1	-15.8 ± 7.0	-12.0 ± 7.4
Peak Flexion Angle (°)	-41.5 ± 7.8	-48.9 ± 15.5	-56.6 ± 17.4	-55.1 ± 8.1
Hip				
Angle at Touch Down (°)	27.7 ± 5.5	**17.5 ± 3.5***	**18.0 ± 7.4***	**17.0 ± 7.1***
Angle at Take-Off (°)	-18.2 ± 8.2	**1.3 ± 3.1***	**0.7 ± 2.4***	**0.6 ± 4.2***
Ground Contact Times	0.098 ± 0.005	**0.170 ± 0.031***	**0.182 ± 0.034***	**0.181 ± 0.027***

[1]: n = 5, as one athlete was unable to complete jump over 0.90 m hurdle.

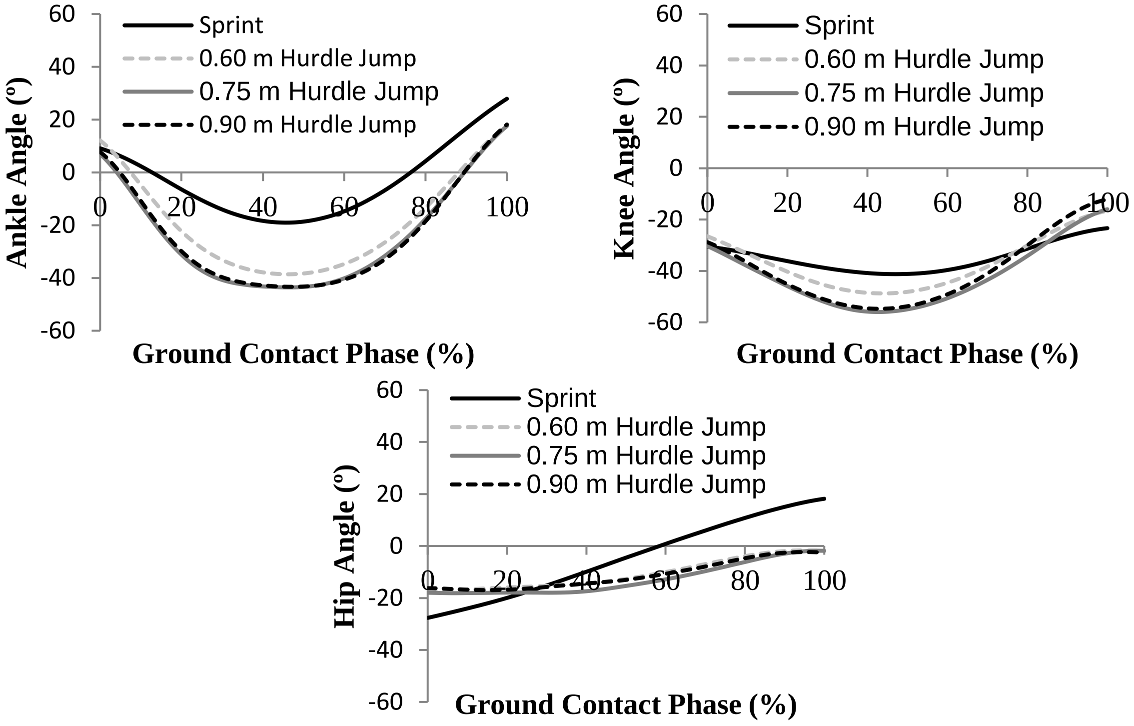

Figure 1: Mean ensemble of the ankle, knee, and hip angle during sprinting (solid black), 0.60 m hurdle jump (broken grey), 0.75 m hurdle jump (solid grey) and 0.90 m hurdle jump (broken black).

DISCUSSION: Contact times during maximal velocity sprinting (0.098 s) and hurdle jumps (0.170 – 0.182 s) are consistent with those previously reported in the literature (Weyand et al., 2010, Cappa & Behm, 2011). Shorter contact times during sprinting can potentially be explained by several factors. The athletes' centre of mass will likely have a greater horizontal velocity at touchdown during sprinting and, consequently, will cover the stance distance quicker. Additionally, a higher negative vertical velocity on touchdown is expected in the hurdle jump conditions relative to the sprint; this would require more time spent applying force to reverse the vertical velocity of the centre of mass and subsequently develop a net positive vertical impulse sufficient to clear the height of the succeeding hurdle.

Athletes can clear a hurdle by raising their centre of mass, achieved by lifting their feet closer to their centre of mass through greater hip flexion, developing a greater vertical impulse and thus higher vertical take-off velocity or through a combination of both. Coaches should therefore monitor the contact times and performance strategies their athletes utilise to clear hurdles of varying height. If contact times are considered excessively long e.g. > 0.25 s, lower hurdles may be required.

As illustrated in Figure 1, on touchdown in all conditions, the ankle achieves peak dorsiflexion just before mid-ground contact and then undergoes plantar flexion until take-off. Significant differences were found in the peak dorsiflexion angle with all hurdle jump conditions displaying significantly greater dorsiflexion than maximal velocity sprinting which suggests that the shank travels further in front of the foot segment during hurdle jumps. The mean ensemble of the knee angle, illustrated in Figure 1, all follow a similar trend. Consistent with previous research, on touchdown, the knee progressively undergoes flexion until peak knee flexion is achieved around mid- ground contact (Bezodis et al., 2008). This is subsequently followed by extension of the knee until the point of take-off. There were no significant differences in peak flexion and extension angles. Greater peak knee flexion was expected in the hurdle jump conditions. This is possibly due to a lack of statistical power; however, future work is required to confirm this. The mean ensemble of the hip angle, in Figure 1, illustrates that after landing, the hip angle remains relatively constant, in the hurdle jumps, until just before mid- ground contact and then undergoes extension until the point of take-off. Whereas in sprinting the hip extends from the instant of touchdown until the point of take-off consistent with previous work (Bezodis et al. 2008). The hip angles in maximal velocity sprinting were significantly different from the hurdle jump conditions with greater hip angles at touchdown and lower hip angles at take-off. This is expected as the hip is flexed on touchdown as the centre of mass is positioned behind the stance foot and then the hip extends throughout the stance phase as the centre of mass is projected forward and ahead of the foot.

CONCLUSION: Hurdle jumps performed over 0.60, 0.75 and 0.90 m had significantly longer contact times and greater peak dorsiflexion angles compared to maximum velocity sprinting. Training with a range of hurdle heights is recommended provided an athlete can maintain relatively short and consistent contact times. If an athlete is not sufficiently conditioned to manage higher landing velocities a large increase in contact times is to be expected. Consequently, coaches should carefully monitor an athlete’s contact time during the performance of the hurdle jump exercise.

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