ANALYSIS OF KINEMATICS DURING SPRINT RUNNING AND DIFFERENT TYPES OF JUMPS

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This study aimed to compare sprint running and various horizontal jumps in terms of speed and step kinematics, focusing on speed versus distance and their relationship with maximal running speed. Twelve female sprinters performed sprints, single-leg jumps for distance and speed, and bounding for distance and speed. The findings showed significant differences in kinematics between sprinting and jumping. Positive correlations were found between sprint speed and single-leg jump speed and distance, step length in all jumps, and contact and flight time in some. No significant correlation was found between sprint speed and step frequency in the jumps. Bounding for speed closely resembled sprint running in kinematic parameters but had only weak to moderate correlation, whereas speed during single-leg jumps had the highest correlation with running speed.

KEYWORDS: Bounding, single leg jumps, contact and flight times, step frequency and length

INTRODUCTION: In many sports, great demands are placed on some form of speed or sprinting ability. To develop sprinting speed, apart from running, there are a wide range of exercises that can be used. Among these are horizontal multi jumps (Haugen et al., 2019). Commonly used exercises among sprinters include bounding for speed, bounding for distance, and single leg jumps (Mero & Komi, 1994). Lin et al. (2023) showed that horizontal multi jumps for distance correlated up to r=-0.75 with sprint running.
When reviewing research in this field, many studies have investigated the "classic" jumping exercises such as CMJ, drop jumps, multi jumps and single leg jumps for distance and their correlation with sprint running (Lin et al., 2023). But only a few studies have investigated speed bounding and its relationship with sprint running and as far as we know, no one has investigated the relationship between single leg jumping for speed and sprint running.
When bounding for speed, there is a kind of "conflict", as you must do something slow and fast at the same time by jumping far and quickly (fast) in the same exercise. During single leg jumping for speed, the focus is on moving as fast as possible without trying to get as far as possible on each jump, which is the same goal as during sprint running.
Therefore, the aim of this study was to investigate and compare kinematics (step length and frequency, contact and flight time and horizontal speed) during sprint running and different horizontal jumps in female sprinters. Our hypothesis is that the speed during bounding for speed and single leg jumps for speed would produce the highest correlation with sprinting because they have greater horizontal speed due to shorter contact and flight time and their objective is to move as quickly as possible horizontally. Secondly, we hypothesize that the speed during single leg jumps for speed would produce a higher correlation with sprint than bounding for speed because single leg jumps for speed have the same goal as sprint running: to just move horizontally as fast as possible, while bounding for speed is an exercise with conflicting goals: to do something fast and slow at the same time.

METHODS: Twelve female sprinters (age 19 ± 3.4 years, body mass 60.1 ± 5.5 kg, body height 171.6 ± 5.4 m) with a best 100m times of 13.07 ± 0.6 s, participated in this study. After an individualized warm-up, each participant performed two maximum attempts in running shoes at the following exercises in an indoor athletics hall. First sprint, followed by these jumps performed in random order: single leg jump for distance on the left and right foot, single leg jump for speed on the left and right foot, bounding for distance and bounding for speed. The

performance distance was 40 m for the sprint and 30 m for the jumps. Recovery periods between each attempt were between 2-3 min.
The participants' horizontal speed and distance were measured using a laser gun (Noptel Oy, Oulu, Finland), while their step characteristics were recorded using an IMU (Inertial Measurement Unit) equipped with accelerometers, gyroscopes, and magnetometers, which measured movement, orientation, and position. The IMU was fixed to the shoe with tape during the sprint, and an infrared optical contact mat (Ergotest Technology AS, Stathelle, Norway) was used over 30 meters for jumps, capturing contact and flight time by interrupting light beams, synchronized with the laser gun.
The participants' average maximum speed, step length, step frequency, flight time and contact time were measured over 4-6 steps. To assess the effect of exercise on sprint speed and kinematics a one-way ANOVA on each of the variables was performed, with a Holm-Bonferroni post hoc comparison. Pearson's correlation coefficients (r) on sprint speed and kinematics were calculated to find the relationships between sprint and horizontal jumps parameters. The level of significance was set at $p < 0.05$.

RESULTS: A significant effect of exercise for each of the variables ($F \geq 135$, $p \leq 0.001$, $\eta_p^2 \geq 0.93$) was found. Post hoc comparison showed that sprint speed was significantly higher than in the jump exercises, followed by bounding for speed. No difference between bounding for distance and single leg jumps were found, while the lowest speed was measured when performing single leg jumps for distance (Fig. 1).

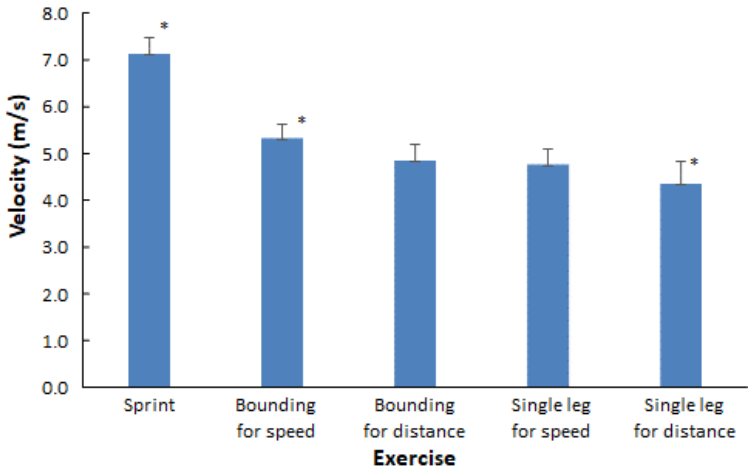

Figure 1. Average (±SD) maximal velocities over 4-6 steps in the different exercises.
*** indicates a significant difference with all other exercises on a p <0.05 level.**

Contact and flight times were the lowest in sprint followed by bounding for speed. Bounding for distance and single leg jumps for speed had similar contact times, while for flight times bounding and single leg jumps for distance had similar longest flight times compared to the other exercises (Fig. 2). Step frequency decreased significantly from sprint – bounding for speed - single leg speed - bounding for distance and single leg jumps for distance, while step length was the lowest in sprint, whilst bounding for distance had the longest step length (Fig. 2).

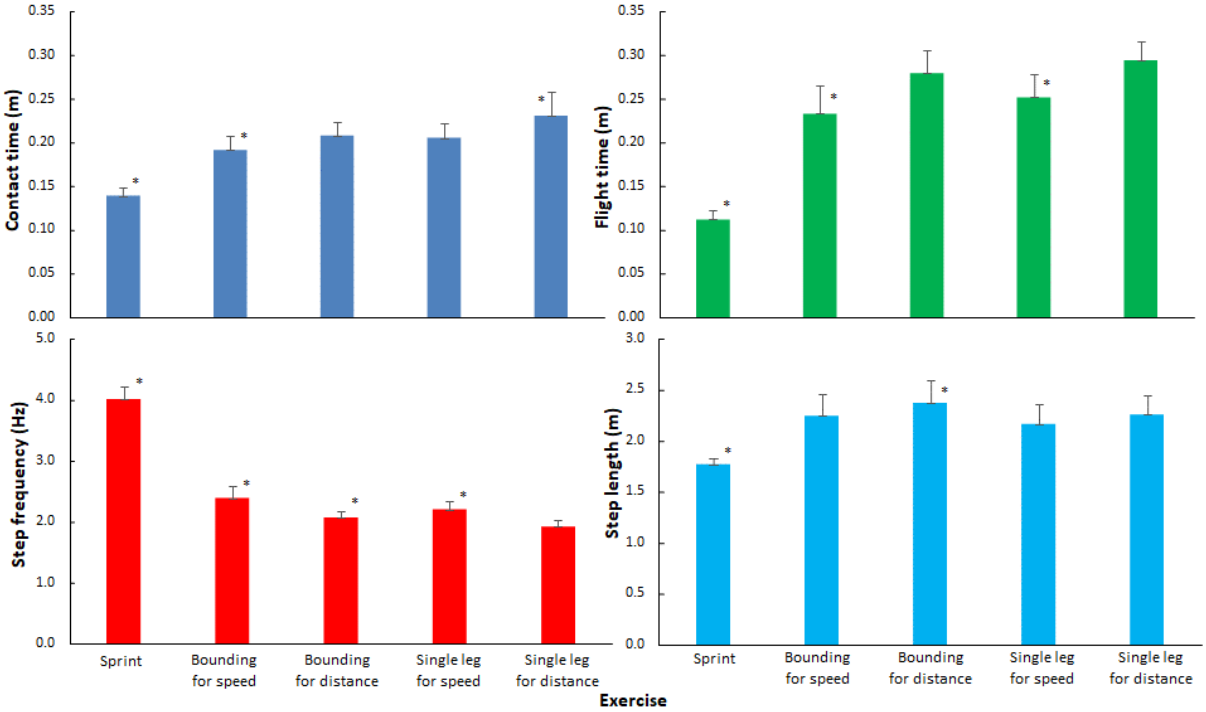

Figure 2. Average ± SD step kinematics at 4-6 steps of maximal speed in the different exercises. * indicates a significant difference with all other exercises on a p <0.05 level.

Correlations with running speed varied from week to very strong. Significant positive correlations were found between sprint speed and the speed of the single leg jump for speed and distance, step length on all the jumping exercises and contact and flight time on some of the jumps. There was no significant correlation between sprint speed and step frequency in any of the jumping exercises (Table 1).

Table 1. Correlation between sprint and different jumps kinematics.

	Correlation with sprint				
	Speed	Step length	Step frequency	Flight time	Contact times
Bounding for speed	0.46	0.58*	- 0.37	0.47	- 0.17
Bounding for distance	0.50	0.69*	- 0.33	0.60*	- 0.42
Single leg jump for speed	0.86*	0.71*	0.03	0.40*	- 0.65*
Single leg jump for distance	0.70*	0.67*	0.35	0.18	- 0.50

* Indicate a significant correlation on p<0.05

DISCUSSION: The aim of this study was to compare kinematics during different horizontal jumps and sprinting in female sprinters. The hypothesis was that the speed during bounding for speed and single leg jumps for speed would have the highest correlation with sprint running and secondly the speed during single leg jumps for speed would correlate more with sprinting than bounding for speed. Our main findings showed the speed during single leg jumping for speed correlated very strongly with running speed while running speed correlated moderately with bounding for speed. These findings partly support our hypothesis.
Of all the jumping exercises, the bounding exercises were the most similar to the sprint races on the various measurement parameters, where bounding for speed had the highest speed, shortest contact time, shortest flight time and highest step frequency. This is consistent with the findings of Mero and Komi (1994). Despite the fact that bounding for speed was most similar to sprinting on the various measurement parameters, it was the speed during single leg

jump for speed that correlated most with maximum running speed with a strong correlation of r=0.86. The speed during bounding for speed correlated only moderately with r=0.46.
Single leg jump for speed does not have the same conflicting goals as bounding for speed. The aim of this exercise is the same as during sprint running: move horizontally as fast as possible without striving for long streps or high frequency.
In the jumping exercises that focused on achieving maximum step length, the correlation between maximum running speed and step length was strong (r=0.67-0.69) This is in agreement with earlier studies (Habibi et al., 2010; Lin et al., 2023; Wibowo & Abdullah, 2017). Bounding for distance had lower speed and frequency and longer contact and flight time than bounding for speed, but still had greater speed and frequency and shorter contact and flight time than both the single leg jump exercises, with the single leg jump for distance being the slowest and with the longest time on the ground and in the air. Although these exercises are very different from sprint running in terms of the various measurement parameters, they show the force you are able to express against the ground. Studies have shown that the best sprinters develop the most force against the ground (Morin & Belli, 2003; Weyand et al., 2000). There may be some limitations to the various measurement techniques for kinematic variables such as potential inaccuracy with the laser gun under varying light and surface conditions, impact on natural running style when attaching the IMU to the shoe, and sensitivity and accuracy issues with infrared mats for jumping.

CONCLUSION: The correlation between jumping exercises and maximal sprinting varied, with single leg jump for speed having the highest correlation. The sprint races showed higher speed, shorter contact and flight time, and higher step frequency compared to the jumping exercises. Bounding for speed was found to be closest to sprinting in terms of all kinematic parameters, but the speed had the lowest correlation with running speed. On the other hand, the speed during single jumping for speed had the highest correlation with running speed. The explanation could be that bounding for speed is a "constructed" exercise where you have to do an exercise slow and fast at the same time, while single leg jumping for speed only requires you to move as fast as possible. This may mean that sprinters should prioritize single leg jumping for speed in their training, but at the same time this should be explored in a training intervention to see if there is a similar connection as in this acute study.

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