Relationship of Step Width with Sprinting Performance and Ground Reaction Forces

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Abstract: The purpose of this study was to clarify the relationship of step width with sprinting performance and ground reaction forces in order to understand the sprinting mechanism and its relation to better sprinting performance.

1 OBJECTIVES

Relationships between sprinting performance and spatiotemporal variables such as step frequency and length have broadly been investigated (Debaere et al., 2013; Hunter et al., 2004; Nagahara et al., 2014). However, little is known about the relationship of step width, which is the mediolateral distance between two consecutive steps, with sprinting performance. For example, Ito et al. (2006) showed step width at initial acceleration and at maximal speed phase during 100-m race. Although they reported no significant difference in the step width between elite and national level sprinters, the result was obtained with the investigation at initial acceleration and maximal speed phase. Thus, when considering the entire acceleration phase of sprinting, an importance of narrower or wider step width may be able to be found.

While a study has investigated the influence of difference in step width on some kinetic variables during running (Brindle et al., 2014), the influence of step width on ground reaction force (GRF) during sprinting has never been examined. Accordingly, it is still unknown how difference in step width associate with GRFs during sprinting.

The purpose of this study was to clarify the relationship of step width with sprinting performance and GRFs in order to understand the sprinting mechanism and its relation to better sprinting performance.

2 METHODS

2.1 Experiment

Seventeen male athletes (mean ± SD: age, 20.7 ± 1.2 y; stature, 1.73 ± 0.03 m; body mass, 66.5 ± 4.2 kg; personal best 100-m race time, 11.22 ± 0.28 s) participated in this study. After warming-up, the participants performed 60-m maximal effort sprinting from starting blocks. GRF over 52-m distance was sampled with 54 force platforms (1000 Hz) connected to a single computer (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan).

2.2 Data Processing

Spatiotemporal variables were calculated at every step during 50-m distance with following procedures. Foot strike and toe-off instants were determined with a threshold of vertical GRF as 20 N. Based on the foot strike and toe-off instants, step duration from the foot strike of one leg to the next foot strike of the other leg was calculated. Step frequency was computed as an inverse of step duration. Foot placement was determined as the centre of pressure position at the middle of the support phase. Step length and width were calculated as anterior–posterior and mediolateral distances between two consecutive steps. For the step width, to standardise the value, ratio of step width relative to the corresponding subject stature was calculated. Running speed was calculated as a product of step length and frequency. Step-to-step mediolateral and anterior–posterior impulses during the support phase
over 50-m distance were calculated from GRF 
signals. Moreover, effective vertical impulse during 
the support phase was computed (Weyand et al., 
2000).

2.3 Statistical Analysis

To examine the relationship among variables during 
accelerated sprinting with macroscopic perspective, 
each variable at all steps during 50-m distance was 
averaged out. Means and standard deviations were 
calculated for each variable. Pearson’s product 
moment correlation coefficient was calculated to test 
relationship among the average variables. The 
significance level was set at 5%. All statistical 
values were calculated using JMP 12 statistical 
software (SAS Institute Japan Ltd, Tokyo, Japan).

3 RESULTS

Averaged running speed, step length and step 
frequency over 50-m distance were 8.20 ± 0.17 m/s, 
1.82 ± 0.10 m, 4.45 ± 0.22 Hz, respectively. Figure 1 
shows changes in step width during the entire 
acceleration phase. The step width from the first step 
after block clearance decreased to the 14th step (3.43 
s), and the magnitude of decrease became small 
afterward during the entire acceleration phase. The 
averaged step width over 50-m distance and its ratio 
were 0.15 ± 0.05 m and 8.9 ± 3.0 % of stature.

Table 1 shows averaged GRF variables over 50-
m distance. The medial (inward) impulse was 
greater than the lateral (outward) impulse while running on straight line.

The ratio of step width was significantly positively correlated with running speed \(r = .484, P = .049\), whereas no significant correlation was 
found between the ratio of step width and step length 
or frequency \(r = .279 \text{ and } .066, P = .279 \text{ and } .800\) 
(Figure 2). The ratio of step width was significantly 
correlated positively with medial \(r = .816, P < .001\), 
lateral \(r = .833, P < .001\), net mediolateral \(r = .880, P < .001\) and propulsive impulses \(r = .539, 
P = .026\) (Figure 2). No significant relationship was 
found between the ratio of step width on the one 
hand and braking impulse \(r = -.447, P = .072\), 
anterior–posterior net impulse \(r = .423, P = .091\) 
and effective vertical impulse \(r = .015, P = .955\) on 
the other hand.

4 DISCUSSION

This study aimed to clarify the relationships of step 
width with sprinting performance and GRFs. The 
results in this study demonstrate the probable 
importance of relatively wide step width for better 
accelerated sprinting performance. Because the 
relationship of step width with both step length and 
frequency did not show significant relationship, the 
benefit of wider step width may have no specific 
effect on longer step length or higher step frequency.

In contrast to the results of this study, Ito et al. 
(2006) reported no significant difference in the step 
width between elite and national level sprinters. The 
reason of this discrepancy may be the difference in 
methodological approach in addition to the 
difference in the performance levels between our 
study and the study by Ito et al. (2006), i.e. sprinting 
was investigated at initial acceleration and at 
maximal speed phase in the study of Ito et al. (2006), 
while it was investigated over the entire 50-m 
distance in this study.

The wider step width was associated with greater 
medial impulse and smaller lateral impulse, as well 
as greater mediolateral net impulse, indicating that 
the wide step width will be accompanied by large 
mediolateral velocity of body within a step. 
Although the mediolateral velocity of body is 
theoretically disadvantageous for better sprinting 
performance, the wide step width is interestingly 
also associated with greater propulsive impulse. This 
result suggests that wider step width may be feasible 
to produce greater propulsive force during the 
support phase of sprinting. While it is difficult to 
clearly explain the mechanism of how wider step 
width induces greater propulsive impulse during 
sprinting, one possible reason is the difference in
Table 1: Averaged GRF variables over 50-m distance. ML and AP mean anterior–posterior and mediolateral, respectively. ML and AP positive values indicate medial and propulsive GRFs. ML and AP negative values indicate lateral and braking GRFs.

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Positive</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML impulse [Ns/kg]</td>
<td>−0.04 ± 0.03</td>
<td>0.13 ± 0.05</td>
<td>0.09 ± 0.07</td>
</tr>
<tr>
<td>AP impulse [Ns/kg]</td>
<td>−0.11 ± 0.02</td>
<td>0.52 ± 0.04</td>
<td>0.40 ± 0.03</td>
</tr>
<tr>
<td>Effective Vertical impulse [Ns/kg]</td>
<td></td>
<td>1.02 ± 0.09</td>
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Figure 2: Relationship of step width with spatiotemporal and GRF variables.

Adductor muscle activations during hip extension between wide or narrow stances. In the study with squat exercise (McCaw and Melrose, 1999), the integrated electromyography values of adductor muscle for the ascent phase of squat with use of a wide stance were approximately 20% greater than that with use of narrow stance. Wiemann and Tidow (1995) indicated the importance of adductor muscles to generate propulsive force together with major hip extensor muscles. Consequently, relatively wide step width during sprinting possibly induces greater activity of adductor muscles and better sprinting performance through greater propulsive force.

In conclusion, the wider step width may be beneficial for better accelerated sprinting performance. This finding may deepen the understanding of sprinting performance and be beneficial for athletes and coaches, trying to improve accelerated sprinting performance.

REFERENCES


