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Relation between block spacing and forces applied to starting blocks by a sprinter

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Abstract

Sprinters adjust the arrangement of their starting blocks prior to a race, but there is no standard approach to doing this. At present, it is unclear as to how the block arrangement affects the forces applied to the blocks and consequent performance during sprint start. The purpose of this study is to investigate the effects of the starting block arrangement on the forces applied to them. For 18 different arrangements of block spacing, forces applied by a sprinter to the front and rear starting blocks, as well as to the ground on the first step, were measured using three force plates. The results indicate that when in the starting posture, the magnitude of the impulse applied to both blocks changes little between the 18 arrangements. Likewise, no substantial change occurs in the forces applied to the ground upon the first step. However, as the distance between the front and rear blocks was changed, the ratio of the impulses applied to the front and rear blocks did change: as the block spacing was increased, the impulse applied to the front block while in the starting posture decreased, while that applied to the rear block increased. In addition, changing the distance from the starting line to the front block influenced the relation between the block spacing distance and the forces applied to the two starting blocks.

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"Keywords: sprint start, block spacing, starting blocks, applied force"

1. Introduction

In a sprint start, athletes are required to accelerate their bodies from a static state. To achieve the strategic starting motion, sprinters adjust the arrangement of the starting blocks prior to a race. Starting block spacing is typically divided into three types, based upon the distance between the blocks [1]: bunch

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start (30 cm or less); medium start (30–50 cm) and elongated start (50 cm or more). From these three types, a sprinter will then use trial and error to fine-tune the block spacing when practicing.

Looking into the relation between the arrangement of the starting blocks and the initial sprint motion, studies have been reported that examined the connection between the arrangement of the blocks and the set position [2]. Further, in recent years, the actual conditions needed in a method for arranging the starting blocks have been investigated, with a wide range of sprinting abilities being targeted [3].

Moreover, Payne & Blader [4] have reported on the forces applied to the blocks as the sprinters leave the starting blocks, and Shinohara & Maeda [5] have reported on the relation between the forces applied to the blocks and the ground reaction force of the first step. However, there have been few studies that investigate in detail the relation of arrangement of the starting blocks with both the forces applied to the blocks and the ground reaction force of the first step [6] [7].

In the present research, arrangement of the starting blocks was described by two factors: the distance from the starting line to the front block and the distance between the blocks. The purpose was then to ascertain the influence of these two factors upon both the forces applied to the blocks and the ground reaction force of the first step. In addition, the relation between the performance of sprint start and the block spacing was explored.

2. Method

Participant

The participant was a sprinter with an athletic career of more than 10 years (height: 159.8; cm; weight: 57.5 kg; and personal best 100-m time: 11.43 s). The participant positioned the left leg on the front block. The content of the experiment was explained to the participant, and upon obtaining consent, was subsequently executed.

Measurement setup

To measure the forces applied to the starting blocks, three force plates were used (Fig. 1). Two force plates (TP803-5416-5KN, Tec Gihan Inc.), labeled “1” and “2” in Figure 1, were placed under each blocks. Figure 1 shows the forces applied to the rear (F_{x1} , F_{y1} , F_{z1}) and front (F_{x2} , F_{y2} , F_{z2}) blocks, as measured by the force plates along the x -, y - and z -axes, respectively.

The ground reaction force of the first step was measured using a third force plate (9281C, Kistler) (labeled “3” in Fig. 1). Again, Figure 1 shows the ground reaction forces of the first step (F_{x3} , F_{y3} , F_{z3}), experienced by the force plate along the x -, y - and z -axes.

Sprint start experiments

With the starting blocks fixed upon the force plates, the subject did “sprint starts” as done in an actual sprint race, but with bare feet for excluding the effects of spiked shoes. The forces applied to each of the blocks, as well as to the ground during the first step, were measured using the force plates. The sampling frequency assumed for these measurements was 1 kHz.

During the study, the participant performed the sprint starts while varying the block spacing. From the subject’s usual block spacing (B3), the distance from the starting line to the front block (DFB) was changed 3 times, at intervals of 7 cm. For each distance from the starting line, the distance between the blocks (BTW) was changed 6 times, at intervals of 7 cm. Therefore, the participant did sprint starts with 18 different arrangements of block spacing (A1–C6), combining these two factors (Table 1). The participant did 7 starts for each arrangement of block spacing. The order in which the starting block arrangements were tested was random.

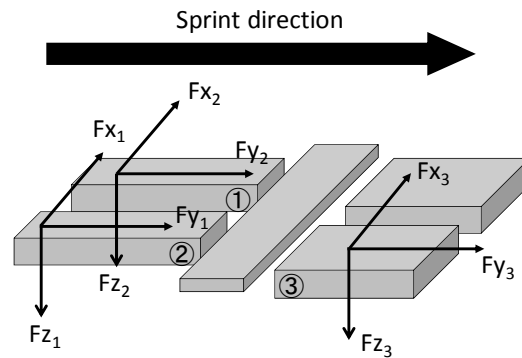


Figure 1: Measurement apparatus and applied forces.

Table 1: Experimental arrangements of block spacing.

Arrangement	DFB ^a (cm)	BTW ^b (cm)	HDCG ^c (cm)
A1	25	3.5	8.1 ± 0.7
A2	25	10.5	9.0 ± 0.9
A3	25	17.5	10.9 ± 0.8
A4	25	24.5	10.2 ± 0.6
A5	25	31.5	13.3 ± 1.2
A6	25	38.5	14.7 ± 1.0
B1	32	3.5	10.7 ± 0.8
B2	32	10.5	11.2 ± 0.7
B3	32	17.5	12.9 ± 1.0
B4	32	24.5	14.2 ± 0.4
B5	32	31.5	15.0 ± 0.7
B6	32	38.5	17.2 ± 0.7
C1	39	3.5	13.7 ± 1.2
C2	39	10.5	13.9 ± 0.9
C3	39	17.5	15.9 ± 0.8
C4	39	24.5	17.3 ± 0.5
C5	39	31.5	19.2 ± 0.7
C6	39	38.5	22.3 ± 0.9

^aDistance from starting line to front block^bDistance between blocks^cHorizontal distance from starting line to body center of gravity

Data analysis

Using the obtained data, the following analysis was performed. Firstly, the impulses applied to the starting blocks were calculated from the composite vector of F_y and F_z . In addition, the impulses applied at the first step were calculated via the ground reaction force for each of F_{x3} , F_{y3} , and F_{z3} . To normalize these impulses, the results were divided by the weight of the participant. Finally, the horizontal distance

from the starting line to the body center-of-gravity position (HDCG) was calculated using Fz_1 , Fz_2 , and the weight of the participant.

In the next section, the relation between HDCG in each block spacing arrangement and the various analysis items is examined. We took $p < 0.05$ to indicate significance.

3. Results

Figure 2 shows HDCG for each block spacing arrangement and the distance of the each block from the starting line. As BTW was increased, HDCG tended to increase. When DFB was increased for the same BTW, HDCG again tended to increase. The distance of each block from the body center-of-gravity position tended to increase as the front block was set further back from the starting line. Moreover, when BTW was large (i.e., the rear block was set further back relative to the front block), the horizontal distance between the body center of gravity position and front block became small and the horizontal distance between the body center of gravity position and the rear block became large.

Figure 3 presents the relation between HDCG and the impulses applied to the blocks. Figure 3 shows that, for the 18 arrangements, there was little change in the impulse applied to both of the starting blocks when in the starting posture.

The correlation between the impulse applied to the rear block and to the front block is shown in Figure 4. As a significant, negative correlation exists between the impulses on each block ($r = -0.94$, $p < 0.05$), and thus the impulse on each block was affected reciprocally by the block arrangement.

Finally, as shown in Figure 5, no significant relation was found between HDCG and the impulse applied at the first step.

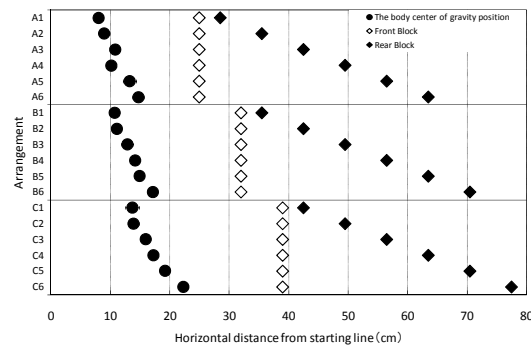


Figure 2: The body center of gravity position and distance from the starting line of the blocks for each block spacing arrangement.

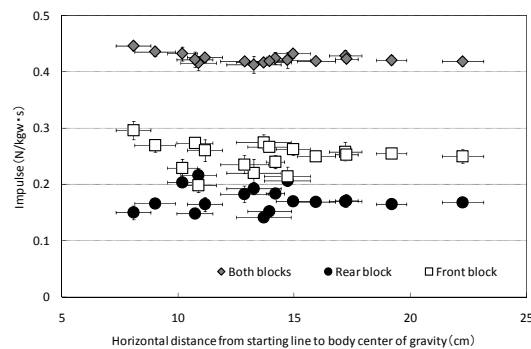


Figure 3: Relation between HDCG and impulses applied to the rear and front starting blocks.

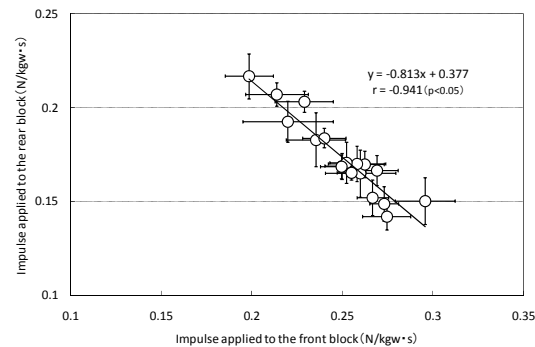


Figure 4: Relation between impulses applied to the rear and front starting blocks.

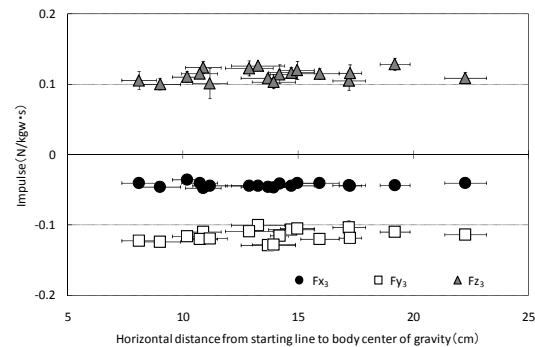


Figure 5: Relation between HDCG and impulses applied at the first step.

4. Discussion

The arrangement of block spacing, due to the positions of an athlete's feet, appears to decide the set position of a crouch start when sprinting. Ito *et al.* [8] reported that when block spacing is changed, HDCG is altered correspondingly. In the present study, HDCG changed when the block spacing was varied, and when the position of each block was changed. Therefore, it is again thought that the set position is changed when the block spacing is rearranged. In both [8] and the present research, the participant was not instructed to consider their set position; it can thus be assumed that the results were caused by taking natural set positions, dependent upon the arrangement of the block spacing. Therefore, based upon HDCG values, the influence of the two factors describing the arrangement of block spacing could be examined.

For a sprint start, the impulses are important to accelerate the body from the set position. Figure 3 indicates that, in a starting posture, the size of the impulse applied to both the front and rear starting blocks changed little between the 18 arrangements. However, the impulse applied to each block was change by rearranging the blocks. It is inferred from these results that the block spacing causes an adjustment in the positions of the sprinter's hands relative to each block in the set position, which changes the body center of gravity position accordingly. This is confirmed by the results shown in Figure 2; changing the distance of the rear and front blocks changes the body center of gravity position in turn. The position of the blocks determines the direction of force acting on the center of gravity; therefore, it is thought that, because altering BTW changes HDCG, the force applied to each block must be different to

generate the force required to accelerate the body center of gravity. Thus, in the final analysis, it is assumed that use of a sprinter's legs, when applying force to the blocks, changes due to the initial conditions being different when the block spacing is rearranged. Additionally, utilization of the blocks changed with the block spacing as the impulses applied to the blocks were related (Fig. 4).

In contrast, Figure 5 indicates that no substantial change occurred in the forces applied to the ground at the first step for different block spacings. Although it can be presumed that similar contact upon the blocks occurs, it is counterintuitive that contact at the first step remains unchanged for different block spacing arrangements. Hence, it is speculated that the manner of applying force at the first step was an individual characteristic of the participant.

5. Conclusions

In this study, the effects of the arrangement of sprint starting blocks upon the forces applied to the blocks, and upon the ground reaction force of the first step, were investigated. The arrangement of the block was adjusted through two factors: the distance from the starting line to the front block (DFB) and the distance between the blocks (BTW). As a result of the analysis, the following points were clarified.

For different block spacings, as BTW and DFB were increased, HDCG tended to increase. Even with considerable variation in the 18 arrangements of the block spacing, the impulses applied in the starting posture to the front and rear blocks changed little. Likewise, no substantial change occurred within the forces applied to the ground upon the first step. However, the impulses applied to the rear and front blocks were related.

As a result, when examining the arrangement of starting block spacing for an athlete, it is suggested that it is necessary to consider how both the rear and front blocks are used by the sprinter and the influence on the set position of changing the block spacing arrangement.

However, the findings of this study should be noted that this is applicable to single subject. Future, we need to sample a greater number of participants in order to determine any generality.

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