ASSOCIATION OF CHANGES IN SPATIOTEMPORAL VARIABLES AT EACH STEP WITH 100 M SPRINT PERFORMANCE IN PREADOLESCENT SPRINTERS.

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The purpose of this study was to investigate the association of acceleration and changes in spatiotemporal variables at each step with 100 m sprint performance in preadolescent sprinters. Twenty-six boys performed 100 m sprints, and their spatiotemporal variables were measured at each step. Acceleration was negatively correlated with the 100m sprint time from the 1st to 21st step. The rates of change in step frequency were positively correlated with acceleration at the 2nd and 3rd step. Aftter the 3rd step, rates of change in step length were positively correlated with acceleration. The acceleration caused by increase in step frequency and step length up to reaching to the maximal sprint velocity is effective for improving the 100 m sprint time in preadolescent sprinters.

KEYWORDS: elementary school student, sprint running, acceleration, step length, step frequency.

INTRODUCTION: Short sprint running (≤ 100 m) is one of the most important skill for not only adults but children in almost all sports. Sprint time is strongly correlated with maximal sprint velocity (Volkov & Lapin, 1979). The acceleration period is limited to about 5 to 7 s owing to depletion of the high-energy phosphate stores (Hirvonen et al., 1987). Therefore, higher acceleration within the limited time would be important for higher maximal sprint velocity and consequently contribute to shorter 100 m sprint time. In fact, some previous studies reported that the ability of a sprinter to accelerate by the time to achievement of the maximal sprint velocity was primarily important to the sprinter (Morin et al., 2011; Nagahara et al., 2014). However, the duration from achievement of maximal sprint velocity to the finish line is about two times as the time from start to the maximal sprint velocity in children, especially elementary school students, because of the longer overall 100 m sprint time compared with adult sprinters. From these facts, it is suggested that the smaller deceleration after having achieved the maximal sprint velocity is also important for improving 100 m sprint time in children.
Sprint velocity is determined as the product of step frequency (SF) and step length (SL). Nagahara et al. (2014) reported that these spatiotemporal variables individually change during the acceleration phase in sprint running. It was also obtained that rates of increase in SF up to the 3rd step and rates of increase in SL from the 5th to 15th step was effective for acceleration at each step. However, no study has clarified the changes in these spatiotemporal variables at each step during a complete 100 m sprint, and relationships between the changes in spatiotemporal variables at each step and sprint performance in children. Therefore, the purpose of this study was to investigate the association of acceleration and changes in spatiotemporal variables at each step during 100 m sprint running with sprint performance in preadolescent sprinters.

METHODS: Twenty-six boys participated in this study (mean ± SD; age 10.8 ± 0.9 years, 140.2 ± 6.9 cm, 32.5 ± 5.2 kg). Their maturity status was evaluated by years from peak height velocity estimated by a maturity offset, which was derived from anthropometric data (Mirwald et al., 2002) and was assessed as pre-peak height velocity (−3.71 ± 1.12 years). All participants belonged to the track-and-field athletic sports club and had been specifically coached in sprint running training once a week. All participants and their parents were informed of the experimental procedure and provided written consent to participate in this study. Each participant performed one maximal effort 100 m sprint from the standing start on an all-weather track following an adequate warm-up. The start signal was the sound of an electronic starting device (JESTAR, NISHI, Japan). The sprint velocity curve (instantaneous speed) through the entire 100 m sprint was measured by a laser measurement device (LAVEG; LDM301S, Jenoptik, Germany; 100 Hz). This device on a 1.2-m tripod was placed at about 15 m behind the start line. The laser beams were constantly directed at the participant's back during the sprint. Moreover, while running the participants were constantly recorded by two panning cameras (GC-PX1, JVC, Japan; 300 fps) covering 5 m behind the start line to 60 m and 45 m to 105 m at 35 m and 75 m from the start line at 40 m to the right of the center of the running lane. The data of time-distance changes were smoothed by a Butterworth digital filter, with a cutting off frequency of 1.0 Hz, and the changes in velocity were calculated by differentiating the smoothed time-distance measures (Shinohara & Maeda, 2016). Every device was synchronized with the electronic starting device. 100 m sprint time was determined as the time from the start signal to the achievement of the 100 m distance by the LAVEG. Maximal sprint velocity, the distance (d_{max}) and the duration (t_{max}) from start to maximal sprint velocity were observed by LAVEG. The times of foot contact and toe-off instants during sprint running at each step were measured by the number of frames recorded by the cameras. Each step duration was defined as the time from the foot contact of one leg to the next foot contact of the other leg. The positions of each foot contact from the start line were determined by corresponding to the data of time-distance by the LAVEG. SF was calculated as the inverse of step duration. Support time (ST) was defined as the duration from foot contact of one leg to toe-off of same leg. Flight time (FT) was defined as the duration as the duration from toe-off of one leg to foot contact of the other leg. SL was calculated as the difference of positions between two consecutive steps. Additionally, sprint velocity was calculated as the product of SF and SL. Based on the methods in a previous study (Nagahara et al., 2014), spatiotemporal values were approximated against the time axis using a fourth-order polynomial to cancel bilateral differences and awkward movements of children. Since the minimum numbers of steps of the sprinter who had the longest SL was 58 steps, the number of steps for calculation in all participants was unified to 58 steps. Thereafter, acceleration and rates of change in SF, SL, ST and FT (RSF, RSL, RST and RFT, respectively) were derived from approximated data.

RESULTS and DISCUSSION: The mean 100 m sprint time was 17.23 ± 1.23 s. The mean maximal sprint velocity was 6.54 ± 0.45 $m \cdot s^{-1}$ at the 20.0 ± 1.3th step (ranged from the 18th to 22nd step). The d_{max} was 29.6 ± 7.4 m, and the t_{max} was 5.64 ± 1.04 s. Maximal sprint velocity was significantly correlated with 100 m sprint time (r = −0.979, P < 0.001).

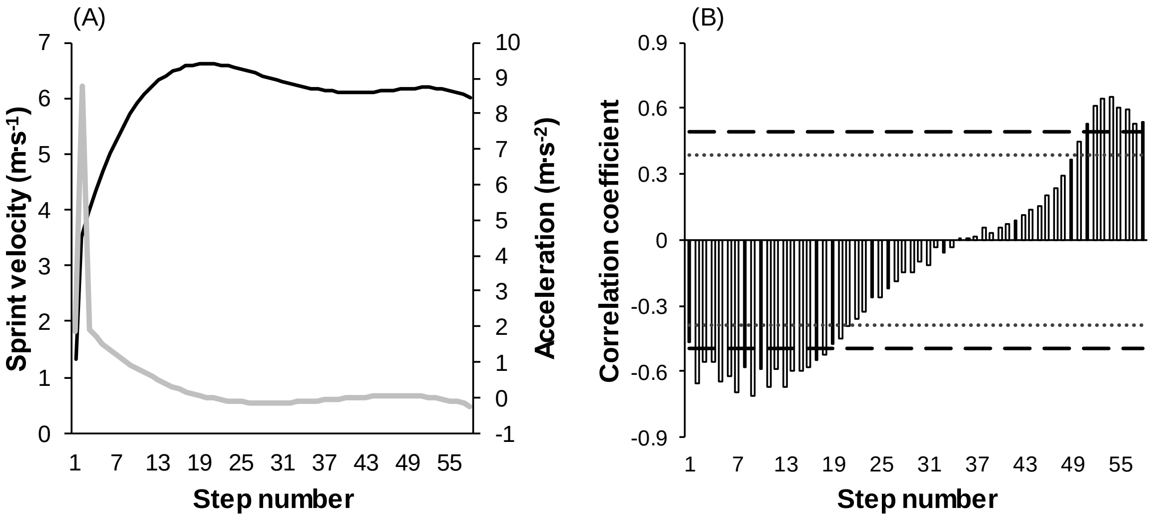

Figure 1: Mean data of sprint velocity (black line) and acceleration (gray line) at each step (A) and change in the correlation coefficient between 100 m sprint time and acceleration (B). Dotted horizontal gray lines show the significance level as p = 0.05. Broken lines show the significance level as p = 0.01.

This result supports previous studies which have examined the relationship between maximal sprint velocity and 100 m sprint time in adult sprinters, while step number at the maximal sprint velocity compared less frequently with adult sprinters (ranged from the 22nd to 25th step; Nagahara et al., 2014). No significant correlation was found between the t_{max} and both the 100 m sprint time and the maximal sprint velocity. On the other hand, d_{max} significantly correlated with both 100 m sprint time and maximal sprint velocity ($r = -0.486$, $p = 0.012$; $r = 0.451$, $p = 0.021$, respectively). The t_{max} in this study corresponded to that in adults, but the d_{max} did not. The t_{max} depends on the high-energy phosphate stores. Children might have a similar metabolic system for muscular fatigue during sprint running as adults. Although it is known that SF does not increase with aging, the step number at maximal sprint velocity in children was different from that in adult sprinters. The 100 m sprint time in our study was not high level, thus, the different levels in sprinting would explain the difference in step number for maximal sprint velocity.

Figure 1 (A) shows the mean data of sprint velocity and acceleration at each step. The acceleration values rapidly increased, especially at the 2nd step, and then slightly diminished to the last step. Figure 1 (B) shows the changes in the correlation coefficients between the 100 m sprint time and acceleration. The 100 m sprint time and values of acceleration at each step were found significant negative correlation from the 1st to the 21st steps ($r = -0.713$ to -0.392) and significant positive correlation from the 50th to the 58th steps ($r = 0.445$ to 0.652).

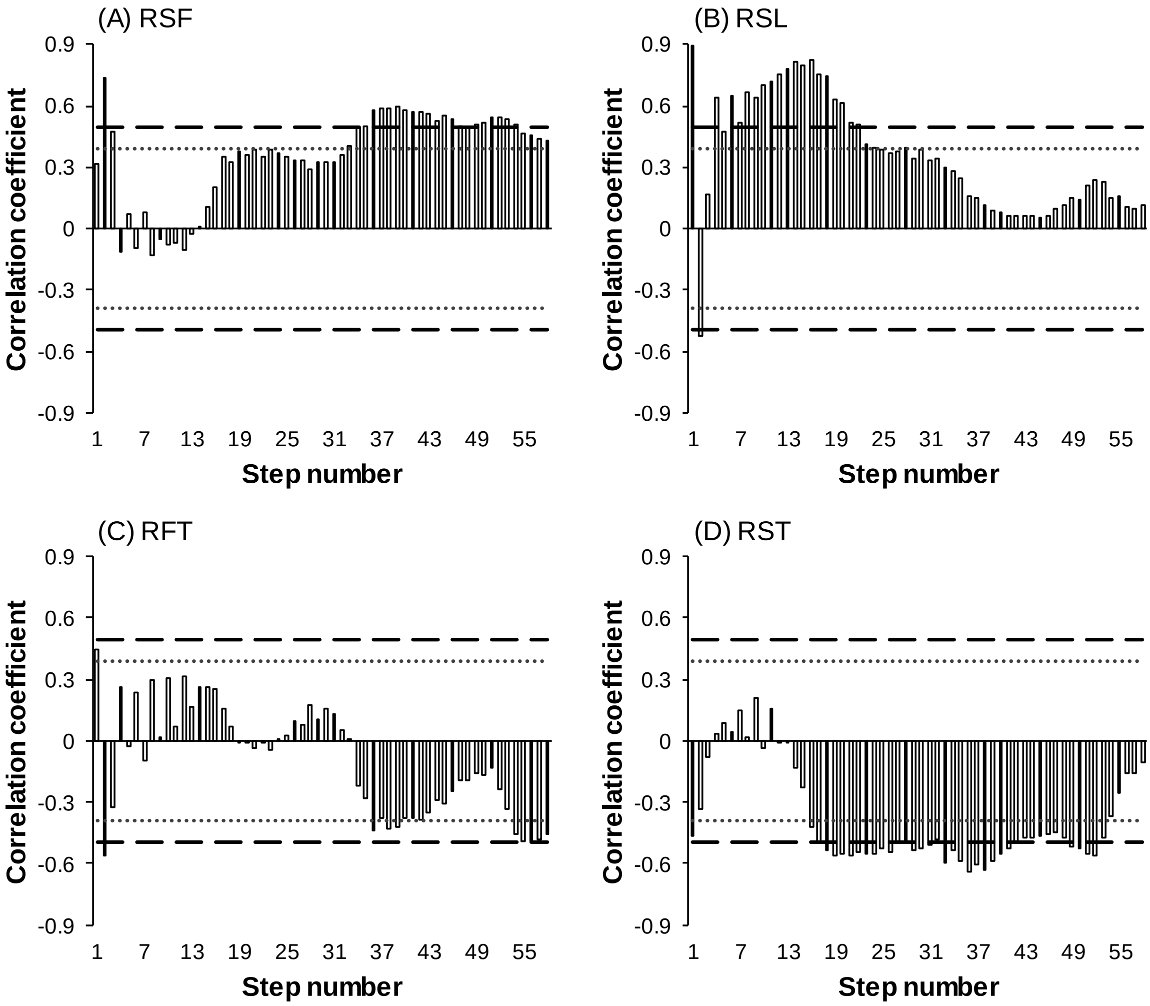

Figure 2: Changes in the correlation coefficients between acceleration and rates of changes in spatiotemporal variables (A: RSF, B: RSL, C: RFT, D: RST). Dotted horizontal gray lines show the significance level as *P* = 0.05. Broken lines show the significance level as *p* = 0.01.

Figure 2 shows the changes in the correlation coefficients between acceleration and rates of changes in spatiotemporal variables. There were significant positive correlations between RSF and acceleration at the 2nd and 3rd step and from the 33rd to 58th step (*r* = 0.390 to 0.740). There were significant positive correlations between RSL and acceleration from the 1st to 24th steps, except for the 2nd and 3rd step, and at the 28th step (*r* = 0.391 to 0.894). A significant negative correlation between RSL and acceleration was found at the 2nd step (*r* = −0.527, *P* = 0.006). There were significant negative correlations between RFT and acceleration at the 2nd, 36th, 38th, 39th and from the 54th to 58th step (*r* = −0.563 to −0.421). There were significant negative correlations between RST and acceleration from the 16th to 53th step (*r* = −0.642 to −0.419). Regarding to the 1st step, it was found that acceleration positively correlated with RFT and negatively correlated with RST (*r* = 0.441 and −0.466, respectively). From the 1st to 21st step, the accelerations at all steps were important for higher maximal sprint velocity. There were positive relationships between RSF and acceleration at the 2nd and 3rd step. Posterior to the 3rd step, increases in RSL were effective for increases in acceleration. Furthermore, continuations to maintain or decrease the ST were important for increasing sprint velocity and/or keeping sprint velocity from the 16th step. It is suggested that the acceleration phase is divided into several sections similar to those for adult sprinters. On the other hand, positive relationships between acceleration and 100 m sprint time were found from the 50th to 58th step. This result demonstrated that maintenance of sprint velocity was not necessary for shorter 100 m sprint time despite the initial hypothesis in this study. It should be clarified whether the higher deceleration is independently associated with superior sprint performance or boys who are faster in 100 m sprint than others cannot maintain the sprint velocity at the last few steps. Further studies are needed to elucidate whether similar relationships were observed in various sprint level boys.

CONCLUSION: This study aimed to investigate the relathionships among acceleration, changes in spatiotemporal variables at each step during 100 m sprint, and sprint performance in preadolescent sprinters. The results suggest that accelerations caused by RSF at the first 3 steps and RSL from the 4th to 21th step were important for shorter 100 m sprint time. These findings suggest that sprint training up to the 21 th step or a place where boys could run at least 21 steps are suficient for improving the sprint performance in elementary school boys. However, further studies are required to investigate whether the skill to keep the sprint velocity at the last few steps is important for shorter 100 m sprint time.

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