CONCURRENT VALIDITY OF VIDEO-BASED MTHOD TO OBTAIN STEP LENGTH DURING SPRINT ACCELERATION

Tadahiko Kato[1], Hirofumi Kintaka[2], Daisuke Komori[2] and Ryu Nagahara[2]

Kyushu Sangyo University, Fukuoka, Japan[1]
National Institute of Fitness and Sports in Kanoya, Kanoya, Japan[2]

This study aimed to examine validity of the video-based method for obtaining step length during sprint acceleration when compared with the center of pressure (COP) position. Four well-trained male sprinters performed 50-m sprint for eight times each. The foot location and step length were obtained using video image for 24 steps. The Intra-class correlation coefficients between COP position and video-based method showed high validity (>0.847) for foot location and step length. Although there was a significant magnitude-error correlation (r = −0.972) for the foot location, corresponding correlation was not significant for step length (r = 0.081). Accordingly, the results suggest that video-based method has enough validity for obtaining step length during sprint acceleration when compared with COP position.

KEYWORDS: running, 2-D DLT method, practicality

INTRODUCTION: The running velocity changes step to step during sprint acceleration (Mackala, 2007), and the running velocity is calculated as a product of step frequency (SF) and step length (SL). Thus, these spatiotemporal variables are useful to evaluate sprint acceleration performance. Furthermore, SF and SL have been calculated for understanding underlying sprinting techniques (Nagahara, Naito, Morin, & Zushi, 2014; Plamondon & Roy, 1984; Toyoshima & Sakurai, 2018). SF can be easily calculated using high-speed videos by counting the frames at the foot contact. Although the SL can also be obtained using one camera and visible known marker locations, the validity of the video-based SL determination method using one camera is unclarified. Therefore, the purpose of this study was to examine the validity of the video-based method for obtaining foot locations during sprint acceleration using one camera.

METHODS: Four well-trained male sprinters (age, 21.0 ± 0.8 years; stature, 1.73 ± 0.02 m; body mass, 67.2 ± 1.6 kg; personal best 100-m time, 11.12 ± 0.22 sec) participated in this study. All of them provided written informed consent to participate in this study.
The data collection in this study was performed in an indoor experimental site. Participants performed 50-m sprints for eight times at different self-regulated effort levels (60–100 %). The sprint was treated as a 100-m race with starting blocks, and the participant used his own crouched starting position. The surface of the running lane was the same as that of an official outdoor athletic track. Fifty-four force platforms (1000Hz, TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan) connected to a single computer measured center of pressure (COP) position at each step during sprinting (gold standard). A camera (HDR-CX675, Sony, Tokyo, Japan) was used to record the sprinting motion at 60 Hz with a shutter speed of 1/500 s. The camera was placed on the left side of the running lane. The camera was fixed up on the tripod perpendicular to the running late at the 30-m mark from the starting line due to the restriction of the experimental site, and the distance from the running lane to the camera was 47 and 10 m in the horizontal and vertical direction. Fifty-two reference markers were placed on both sides of the running lane with intervals of 2-m in the running direction.
As a foot location obtained using force platforms, mean of COP positions in the anterior–posterior direction for 10 frames during the middle of the support phase was calculated at each step. For the video-based method, two-dimensional panning direct linear transformation (DLT) method was used to obtain the foot location. In this method, coordinates of all reference markers were digitized beforehand. Then, locations of the tip of the ground contact shoe and clearly visible one reference marker in the same frame were digitized for obtaining the foot location at each step. All digitizing procedures were performed using the Frame-DIAS V system

(DKH Co., Tokyo, Japan). For both methods, SL was calculated as the distance between foot locations at the consecutive two steps in the anterior–posterior direction. Because the location of the front block at the start was unknown, SL from the block clearance to the first step could not be calculated.

The total number of trials for analysis was 32. Means and standard deviations were calculated for all variables. The range of total steps for 50-m sprint were from 24 to 27 in each trial, and thus the statistical analyses were performed for 24 steps. For the location of the ground contact foot, difference and its 95% confidence intervals (CIs) in values between video-based and force platform basis methods were computed. For SL, the difference and its 95% CIs in values between two methods were calculated as a ratio (% of SL obtained by force platform basis method). Intra-class correlation coefficient (ICC) and its 95% CIs were obtained to evaluate the validity of data from video-based method when compared with force platform basis method. Differences of SL between the two methods for each step were also indicated with Bland-Altman plot. Significant level was set at < 0.01. All statistical analyses were performed using the SPSS version 22.0 (IBM, Tokyo, Japan).

RESULTS and DISCUSSIONS: Table 1 shows foot locations obtained by two different methods for 24 steps. The average difference in the foot locations between two methods was 0.036 m for the entire steps, ranging from −0.084 m at the 24th step to 0.017 m at the 2nd step. The ICCs for 24 steps were >0.967 ($p < 0.01$). However, there was negative correlation ($r = -0.972$) of the average of foot locations obtained from COP and video-based method with its error value. This indicates that the error value increases with increasing foot location values. These results indicate that although the errors in foot locations will be small obtained using the video-based method, the method is not accurate enough for obtaining foot location during the entire sprint acceleration.

McLean et al. (2004) reported the relationship between prediction error and yaw angle of camera position against calibration plane in 2-D DLT method, and the error increased as the yaw angle of camera position increased. Thus, it is assumed that the yaw angle of camera position against calibration plane was changed step to step from the initial acceleration to the 50-m mark. Additionally, it is commonly known that the ground contact motion is affected with change of running velocity.

Table 1: Value, difference and intra-class correlation coefficients among foot location for each step obtained from center of pressure positions and video-based method.

Step number	COP [m]	Video [m]	Difference (95% CIs) [m]	ICCs (95% CIs)
1	0.606 ± 0.071	0.592 ± 0.083	0.015 (0.005 - 0.024)	0.967 (0.933 - 0.984)
2	1.750 ± 0.083	1.733 ± 0.089	0.017 (0.009 - 0.026)	0.971 (0.941 - 0.986)
3	3.098 ± 0.134	3.088 ± 0.139	0.010 (0.002 - 0.018)	0.992 (0.984 - 0.996)
4	4.580 ± 0.181	4.568 ± 0.194	0.011 (0.004 - 0.018)	0.996 (0.992 - 0.998)
5	6.206 ± 0.249	6.204 ± 0.262	0.002 (-0.007 - 0.010)	0.998 (0.996 - 0.999)
6	7.924 ± 0.314	7.918 ± 0.318	0.006 (-0.002 - 0.014)	0.999 (0.997 - 0.999)
7	9.751 ± 0.382	9.748 ± 0.392	0.004 (-0.004 - 0.011)	0.999 (0.999 - > 0.999)
8	11.629 ± 0.439	11.641 ± 0.440	-0.011 (-0.018 - -0.005)	0.999 (0.999 - > 0.999)
9	13.586 ± 0.507	13.585 ± 0.514	0.001 (-0.006 - 0.007)	> 0.999 (0.999 - > 0.999)
10	15.575 ± 0.565	15.607 ± 0.567	-0.032 (-0.037 - -0.027)	0.999 (0.998 - > 0.999)
11	17.621 ± 0.625	17.656 ± 0.629	-0.034 (-0.040 - -0.029)	0.999 (0.998 - > 0.999)
12	19.676 ± 0.685	19.723 ± 0.683	-0.047 (-0.052 - -0.043)	0.999 (0.997 - 0.999)
13	21.776 ± 0.733	21.805 ± 0.734	-0.029 (-0.034 - -0.025)	> 0.999 (0.999 - > 0.999)
14	23.873 ± 0.805	23.899 ± 0.812	-0.026 (-0.030 - -0.021)	> 0.999 (0.999 - > 0.999)
15	26.026 ± 0.857	26.067 ± 0.863	-0.041 (-0.046 - -0.035)	0.999 (0.999 - > 0.999)
16	28.179 ± 0.930	28.224 ± 0.929	-0.045 (-0.051 - -0.040)	0.999 (0.999 - > 0.999)
17	30.369 ± 0.977	30.409 ± 0.984	-0.040 (-0.046 - -0.034)	> 0.999 (0.999 - > 0.999)
18	32.564 ± 1.056	32.618 ± 1.062	-0.053 (-0.059 - -0.048)	0.999 (0.999 - > 0.999)
19	34.779 ± 1.097	34.842 ± 1.097	-0.064 (-0.068 - -0.059)	0.999 (0.998 - > 0.999)
20	36.994 ± 1.172	37.056 ± 1.177	-0.063 (-0.068 - -0.057)	0.999 (0.998 - > 0.999)
21	39.226 ± 1.216	39.299 ± 1.222	-0.073 (-0.077 - -0.068)	0.999 (0.998 - > 0.999)
22	41.478 ± 1.290	41.550 ± 1.298	-0.071 (-0.078 - -0.065)	0.999 (0.998 - > 0.999)
23	43.735 ± 1.329	43.816 ± 1.343	-0.081 (-0.090 - -0.072)	0.999 (0.998 - > 0.999)
24	46.024 ± 1.403	46.108 ± 1.413	-0.084 (-0.092 - -0.075)	0.999 (0.998 - > 0.999)

COP: Center of pressure
CIs: Confidence intervals
ICC: Intra-class correlation coefficient

Table 2: Value, difference and intra-class correlation coefficients among step length for each step obtained from center of pressure positions and video-based method.

Step number	COP [m]	Video [m]	Difference (95% CIs) [%]	ICCs (95% CIs)
1	1.144 ± 0.042	1.141 ± 0.047	0.203 (-0.820 - 1.226)	0.847 (0.687 - 0.925)
2	1.348 ± 0.062	1.355 ± 0.069	-0.527 (-1.404 - 0.351)	0.932 (0.862 - 0.967)
3	1.482 ± 0.060	1.480 ± 0.074	0.107 (-0.586 - 0.800)	0.953 (0.904 - 0.977)
4	1.626 ± 0.076	1.636 ± 0.077	-0.593 (-1.161 - -0.025)	0.972 (0.943 - 0.986)
5	1.718 ± 0.072	1.713 ± 0.076	0.231 (-0.489 - 0.950)	0.945 (0.887 - 0.973)
6	1.827 ± 0.073	1.830 ± 0.084	-0.120 (-0.663 - 0.424)	0.968 (0.935 - 0.985)
7	1.878 ± 0.071	1.893 ± 0.070	-0.808 (-1.259 - -0.357)	0.971 (0.941 - 0.986)
8	1.956 ± 0.072	1.944 ± 0.081	0.626 (0.199 - 1.053)	0.976 (0.951 - 0.988)
9	1.990 ± 0.074	2.022 ± 0.073	-1.638 (-2.012 - -1.264)	0.980 (0.959 - 0.990)
10	2.046 ± 0.065	2.048 ± 0.071	-0.121 (-0.452 - 0.211)	0.980 (0.959 - 0.990)
11	2.055 ± 0.070	2.068 ± 0.068	-0.638 (-0.968 - -0.309)	0.981 (0.961 - 0.991)
12	2.100 ± 0.060	2.082 ± 0.066	0.862 (0.582 - 1.142)	0.983 (0.966 - 0.992)
13	2.097 ± 0.083	2.093 ± 0.090	0.187 (-0.105 - 0.479)	0.990 (0.980 - 0.995)
14	2.153 ± 0.066	2.168 ± 0.070	-0.702 (-0.977 - -0.426)	0.985 (0.969 - 0.993)
15	2.153 ± 0.082	2.157 ± 0.075	-0.212 (-0.502 - 0.077)	0.988 (0.975 - 0.994)
16	2.190 ± 0.061	2.185 ± 0.065	0.231 (-0.095 - 0.557)	0.974 (0.948 - 0.988)
17	2.196 ± 0.090	2.209 ± 0.093	-0.602 (-0.927 - -0.276)	0.988 (0.976 - 0.994)
18	2.214 ± 0.059	2.225 ± 0.053	-0.480 (-0.764 - -0.197)	0.976 (0.950 - 0.988)
19	2.215 ± 0.087	2.214 ± 0.099	0.059 (-0.304 - 0.422)	0.986 (0.971 - 0.993)
20	2.232 ± 0.058	2.242 ± 0.061	-0.452 (-0.728 - -0.176)	0.979 (0.958 - 0.990)
21	2.253 ± 0.102	2.251 ± 0.105	0.068 (-0.233 - 0.369)	0.992 (0.983 - 0.996)
22	2.256 ± 0.061	2.266 ± 0.072	-0.425 (-0.815 - -0.034)	0.965 (0.929 - 0.983)
23	2.289 ± 0.101	2.292 ± 0.101	-0.120 (-0.537 - 0.297)	0.983 (0.965 - 0.992)

COP: Center of pressure
CIs: Confidence interval
ICC: Intra-class correlation coefficient

Okano and Maeda (2015) calculated the center of foot pressure (COFP) during sprint acceleration using sensor insole, and COFP once moved backward at the foot contact and then moved forward toward the take-off. Also, with the increase in running velocity, the moving distance from the rearward to the frontward of COFP became shorter gradually. Moreover, it is also supposed that the ground contact motion changes with increase in running velocity. Therefore, it is suggested that the magnitude-error correlation was caused by changes in yaw angle of camera position and changes of COP position during sprint acceleration.

Table 2 shows SL obtained by two different methods for 23 steps. The average of relative difference (% of SL obtained by force platform basis method) was −0.211%, ranging from −1.638% at the 9th step to 0.862% at the 12th step. The ICCs between COP positions and foot locations obtained using video-based method were 0.847 ($p < 0.01$) at the first step and 0.932 ($p < 0.01$) and more from the 2nd step and thereafter.

Figure 1 shows Bland-Altman plot for SL between two methods. The plot was not regress linearly ($r = 0.081$), and the data points were mostly plotted within 95% limits of agreement (average of relative difference ± 2 × standard deviation of relative difference). Thus, the results

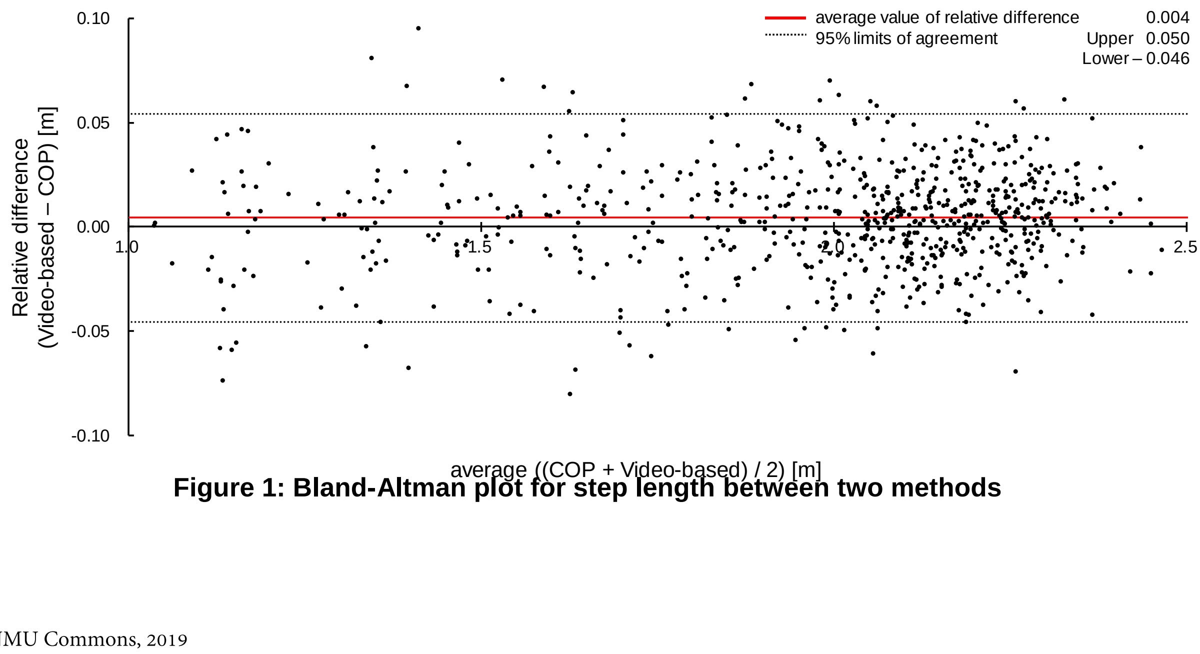

Figure 1: Bland-Altman plot for step length between two methods

suggest that there is no systematic error and no magnitude-error correlation in video-based method for obtaining SL.

Because SL can be obtained using one camera and visible marker locations, video-based determination method for foot location is practical and simple. Thus, it has highly convenient not only for scientists, but also for athletes and coaches.

CONCLUSION: The results of this study suggest that a video-based method using one camera has enough validity for obtaining a step length during sprint acceleration.

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