RELIABILITY AND VALIDITY OF LASER DISTANCE AND VELOCITY DETERMINATION DURING RUNNING

Andrew J. Harrison*, Randall L. Jensen* **, and Orna Donoghue*
***Dept. Physical Education and Sport Science, University of Limerick, Limerick, Ireland**
****Dept. HPER, Northern Michigan University, Marquette, MI, USA**

This study compared the reliability of the laser system with video based kinematic analysis in measuring displacement and velocity. Validity and reliability of the laser on static measures was also assessed at distances between 10m and 70m. Ten subjects completed three running trials at self-determined fast, medium and slow speeds. Running velocity was measured simultaneously by a laser and two video cameras (one at 50Hz, one at 100Hz) within a 3m measurement zone. The reliability of velocity measurements for the 50Hz and 100Hz cameras via intra-class correlation were estimated at R=0.984 (confidence interval 0.95>0.971 to 0.992) and R=0.981 (confidence interval 0.95>0.966 to 0.991) respectively. For the laser, reliability was estimated at R=0.986 (confidence interval 0.95>0.975 to 0.993). One-way repeated measures ANOVA indicated no significant differences (p>0.05) between the three trials for any device. Measurement of running velocity using this procedure was deemed to be valid and reliable.

KEY WORDS: distance, speed, video, laser

INTRODUCTION: Valid and reliable measurement of running velocity is important in many sports analyses. Various devices have been used to measure running velocity, these include optical timing gates (Yeadon et al, 1999) and video (Locatelli and Arsac, 1995). More recently laser and radar have been used but very little published data exists on the validity or reliability of these systems. Optical timing gates provide a rapidly accessible measurement of average running speed within a defined measurement zone. Video analysis can provide similar data but also more detail of time related variations in displacement and running velocity. This involves time-consuming digitization of several body markers but a useful compromise is digitizing a single marker and assuming this provides a reasonable representation of whole body position and velocity. While this is not entirely valid, it may give a reasonable estimate of the overall pattern of movement especially if the marker is attached to a central part of the body such as the hip or trunk. Generally the SVHS video format has been popular and cost-effective in biomechanical applications for some years, however digital video cameras such as the Panasonic DVGRL9000 provide users with the option of picture rates of up to 200Hz (PAL) albeit with reduced spatial resolution.

Laser and radar systems developed for measuring road vehicle speeds have been adapted for measuring running velocity (LAVEG Sport, Jenoptik, Jena, Germany). While the principle of distance measurement using laser is well established, very little published information exists on the validity, reliability and effectiveness of laser distance measurement systems in obtaining distance or velocity-time data during running. It is not known whether laser methods offer an acceptable alternative or improvement on other accepted methods of determining running velocity such as video analysis.

This study had two aims firstly, to examine the validity and reliability of a laser distance measurement device in obtaining static distance measures over a range of distances; and secondly, to compare the reliability of 50Hz SVHS video, 100 Hz digital video and a laser distance measurement in estimating position-time and velocity-time data of humans while running at various speeds.

METHODS: Ten competitive athletes (7 males and 3 females, aged 24.7± 5.0 years) volunteered to participate in the study. All subjects wore a white T-shirt to improve laser reflections and dark-colored cycling shorts to enhance the video digitization process. Subjects completed three running trials on an indoor, synthetic running track at each of three self-defined speeds of 'slow', 'medium', and 'fast' in a random order. Velocity was determined while subjects ran through a 3m long measurement zone located 23.5m from the start point.

A laser measurement device (LAVEG, Jenoptik) sampling at 100Hz, was used to obtain distance measures during all static measurements and running trials. A static measurement validity test was performed on the laser device. For this an A3 sheet of white paper was fixed to a wall, the laser device was mounted on a tripod and located at distances of 10m, 30m, 50m and 70m from the wall. Twelve 3 to 4 second trials were obtained at each distance.

For the running trials, two fixed video cameras (a Panasonic DPH800, operating at 50Hz and a Panasonic DVGRL9000 operating at 100Hz) were located approximately 6.5m on either side of the measurement zone and perpendicular to it. The cameras were placed to ensure that the entire measurement zone remained in view. Marker poles were placed between the measurement zone and the cameras and the positions of the marker poles were adjusted to avoid any parallax errors in the scaling of the area. Reflective markers were placed on the right and left greater trochanters of the subjects and these were visible to the cameras as the subjects ran through the measurement zone. In all running trials, the laser was located 2 meters behind the start position and at a height of 1.37m. The laser was directed at each subject's lower back. Raw distance measurements were obtained within the measurement zone by the laser during each running trial.

The Peak Motus 6.0 video analysis system, (Peak Performance Technologies, Englewood, CO, USA) was used to digitize the video records and determine the position and horizontal velocity of the markers as they passed through the measurement zone. For both cameras, the points where the horizontal coordinate for the hip marker was located between the horizontal coordinates of the fixed marker poles were selected.

The raw displacement data from the laser measurement device and the raw coordinate data sets of the hip markers within the measured zone were exported to Microsoft Excel for filtering and calculation of average velocity within the measurement zone. These data sets included 0.1s of 'data padding' at the beginning and end of the sequences. All data sets were filtered using a Butterworth fourth order, zero lag filter with a 3 Hz cutoff (fc). This was found to be the optimum cut-off frequency following a residual analysis of several typical running trials (Winter, 1990).

The reliability of the static laser tests was evaluated by examining coefficients of variation and intra-class correlation coefficients (ICC) for each of the distances. For the running trials, the reliability of the three devices in estimating the average velocity within the measurement zone at each of the three running speeds was estimated by using a one-way repeated measures ANOVA and intra-class test-retest correlation (Morrow and Jackson, 1993). Comparisons of the three devices across trials and velocities were made using a three-way repeated measures ANOVA with repeated measures on trials and devices. Devices was considered a within-subjects factor because all three devices determined velocity concurrently.

RESULTS: The results of the static tests on the laser at 10m, 30m, 50m and 70m are presented in Table 1. Intra-class correlation coefficients and ANOVA tests for the static tests at each distance provide a further analysis of the reliability of the laser. This analysis involved the calculation of ICC's for 200 cases (samples) across 12 trials at each of the four distances. The results of these tests on raw and filtered laser estimates for both single and multiple samples are presented in Table 2. The ANOVA results indicate significant differences in distance estimates between trials at all four distances ($p < 0.001$). The ICC analysis was repeated on the laser-estimated distance determined as the mean of 200 sample points of raw data. In this case, the ICC analysis involved 4 cases (i.e. distances) and 12 trials. The results of this analysis provided an ICC reliability coefficient of 1.000 and the ANOVA on these indicated no significant differences in mean distance estimates between trials. The results of the test-retest reliability for average velocity in the measurement zone are shown in Figure 1. For the 50 Hz and 100Hz cameras, the ICC reliability of velocity was $R=0.984$ (confidence interval 0.95 > 0.971 to 0.992) and $R=0.981$ (confidence interval 0.95 > 0.966 to 0.991) respectively. For the laser, velocity reliability was $R=0.986$ (confidence interval 0.95 > 0.975 to 0.993).

Table 1 Reliability analysis of raw and filtered data from static laser distance measurement at 10m, 30m, 50m and 70m.

Criterion Distance (m)	Raw Mean Laser estimate (m)	CoV (%)	Mean Error (mm)	Filtered Mean Laser estimate (m)	CoV (%)	Mean Error (mm)
10	9.99570 ±.0204	0.204	-4.30	10.0030 ±.0033	0.033	3.05
30	29.98690 ±.0206	0.069	-13.10	29.99425 ±.0038	0.013	-5.75
50	50.0047 ±.0207	0.041	4.66	50.0122 ±.0039	0.008	12.24
70	70.0095 ±.0217	0.031	9.39	70.0170 ±.00502	0.007	17.05

Table 2 Intra class correlation estimates and 95% confidence interval (CI) of raw and filtered data from static laser distance measurement at 10m, 30m, 50m and 70m.

Distance (m)	Raw data Mean 12 tests ICC (95% CI)	Raw data single test ICC (95% CI)	Filtered data Mean 12 tests ICC (95% CI)	Filtered data single test ICC (95% CI)
10	.462 * (.344-.566)	.067 * (.042-.098)	.797 * (.750-.838)	.246 * (.200-.301)
30	.394 * (.262-.511)	.051 * (.029-.080)	.768* (.714-.815)	.216 * (.173-.268)
50	.437 * (.315-.546)	.061 * (.037-.091)	.783 * (.733-.827)	.231 * (.186-.285)
70	.259 * (.098-.402)	.028 * (.009-.053)	.668 * (.592-.736)	.144 * (.108-.188)

* Indicates significant correlation (p<.001).to the distance measured.

The three-way ANOVA revealed no significance differences ($p > 0.05$) across the main effects (devices or trials) or any interactions ($p > 0.05$). However, there was a significant main effect for speed ($p<0.001$) and post hoc comparisons revealed that all three speeds were significantly different.

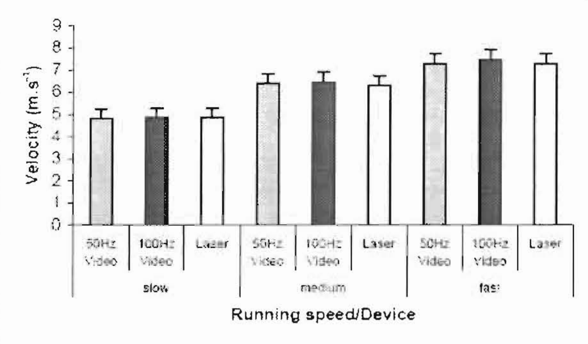

Figure 1: Mean running velocity (m ? sec-1) for three velocities measured via camera at 50 Hz or 100 Hz, or via laser (n=10). The bars indicate 95% confidence intervals.

DISCUSSION: The results of the static tests on the laser indicate that the laser produced valid and reliable measures of distance. The mean errors for distance measurement were less than 0.05% of the measured distances. Further inspection of these errors revealed that they were directly proportional to the distance measured. The results of the ICC's and ANOVA tests on the static distance measurements suggests that relatively low reliability coefficients were obtained with the raw data (R= 0.26 to 0.46). The single sample reliability coefficients were very low. Reliability coefficients for the filtered data were generally higher than the raw data. The ANOVA tests indicated significant differences between trials in all cases. By contrast, the ICC analysis of mean distance estimates (i.e. average of 200 samples) provided an extremely high reliability coefficient, R=1.000 and the ANOVA indicated no significant difference between trials. However, it should be noted that with only four distinctly different distances this correlation would be expected to suffer from stability problems. The ICC tests suggest the need for some caution regarding the reliability of single sample measures in laser measurement. The data suggests that the laser may be subject to low amplitude, high frequency noise, which affects the accuracy of single sample measures.

The intra-class correlation results of the running trials showed that all three devices produced reliable estimates of average velocity within the defined 3m zone. This result is consistent with the results of the static analysis. The results of the three-way ANOVA indicated no significant differences between the devices. Thus, it was concluded that all three devices had high reliability and produced similar results for all measured velocities with a similar degree of effectiveness when used to determine average velocity within a measurement zone. The validity and limitations of video based digitizing systems has been established elsewhere (Ehara et al, 1997) and the results of the validity tests in this study indicate that the laser measurement device provides valid and accurate measurements of displacement/ position. It was concluded that both video cameras and the laser can provide valid and reliable results for the measurement of average velocity within a 3m zone.

It should also be recognized that the displacement measurements obtained by the laser and the video cameras were not identical measures. The laser system measured displacement of the runners' lower back, while the cameras tracked motion of the right and left hip markers. Since these are different landmarks, some differences between the laser and video measures can be expected, although one should expect such differences to be consistent.

CONCLUSION: The results of this study indicate that the laser distance measurement device produces valid and reliable estimates of distance. The laser system is subject to similar levels of high frequency noise as video. Velocity and acceleration data derived from the raw laser distance data will require use of optimal data filtering or smoothing techniques to obtain good results. When used within its limitations, the laser system will provide valid and reliable results, which can be made immediately available to the coach, performer or user without the need to carry out time consuming digitizing procedures.

REFERENCES:

Ehara, Y., Fujimoto, H., Miyazaki, S., Mochimaru, M., Tanaka, S., & Yamamoto, S. (1997). Comparison of the performance of 3D camera systems II. Gait and Posture, 5, 251-255.

Locatelli, E., & Arsac L.M. (1995). The mechanics and energetics of the 100m sprint. New Studies in Athletics, 10(1), 81-87.

Morrow, J.R. Jr., & Jackson, A.W. (1993). How "significant" is your reliability? Research Quarterly for Exercise and Sport, 64 (9), 352-355.

Winter, D.A. (1990) Biomechanics and Motor Control of Human Movement. John Wiley & Sons.

Yeadon, M.R., Kato, T., & Kerwin, D.G. (1999). Measuring running speed using photocells. Journal of Sports Sciences, 17(3), 249-257.

Acknowledgement

This work was sponsored in part by a Northern Michigan University Faculty Sabbatical Grant.