Technical Note

# Accuracy of single beam timing lights for determining velocities in a flying 20-m sprint: Does timing light height matter?

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**ABSTRACT**

Background*:* The purpose of this study was to evaluate the accuracy of timing lights (TL) at different heights for measuring velocities during sprinting. Methods: Two sets of single beam TL were used to determine velocities reached in a flying 20-m sprint in 15 healthy and physically active male participants. In $TL_{64}$, all TL were set up at a height of 64 cm, and in $TL_{100}$, all TL were set up at 100 cm, respectively. Participants performed three valid trials. The recordings of high-speed video cameras were used as a reference. Results*:* ICC and Pearson's r values between both timing light heights and the reference system were almost perfect (0.969–0.991). Bland & Altman's LOA (95 %) indicated low systematic and unsystematic errors, with somewhat smaller LOA for $TL_{100}$ (-0.013–0.121 m/s) than for $TL_{64}$ (-0.060–0.120 m/s). Measures of between-trial reliability of running velocities showed a high relative (ICC) and absolute (RMSE) reliability, with the reference system showing slightly better values in all reliability measures (ICC=0.935; RMSE<0.001 m/s) compared to $TL_{64}$ and $TL_{100}$ (ICC=0.894, 0.887; RMSE=0.107 m/s, 0.124 m/s, respectively). The usefulness, determined by comparing the typical error (TE) with the smallest worthwhile change (SWC), was considered as "OK" (TE ≈ SWC) for all three systems. Conclusions*:* Results suggest that TL at both heights ($TL_{64}$ and $TL_{100}$) can be considered as accurate, reliable, and useful in computing velocities during a flying 20-m sprint,

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and therefore can be recommended to both coaches and researchers. **Key words:** SPRINT PERFORMANCE, TIMING GATES, VALIDITY, HIGH-SPEED VIDEO ANALYSIS, PHOTOCELLS.

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## INTRODUCTION

Linear sprint testing plays a key role in the assessment of physical abilities in different sports (Haugen & Buchheit, 2016). Regarding timing technology, timing lights are commonly employed in order to capture split or total sprint times (e. g., 5 m, 10 m, 30 m) as well as interval times (e. g., 10–30 m) and sprinting velocities over a given interval (e. g. velocity between 10 m and 30 m) (Rumpf, Lockie, Cronin, & Jalilvand, 2016).

Despite the development of progressive technologies such as dual beam or post-processing timing lights, the use of single beam systems is still widespread (Darrall-Jones, Jones, Roe, & Till, 2016; Darrall-Jones, Jones, & Till, 2016; McFarland, Dawes, Elder, & Lockie, 2016; Roe et al., 2017; Sawczuk et al., 2017; Wong et al., 2017), possibly due to greater availability and lower costs (Haugen & Buchheit, 2016).

The validity of single beam timing lights to capture split and total times has been well investigated. Consistently, several researches question the accuracy at short distances (e. g., 5 m, 10 m, 20 m), whereas longer distances (e. g., 30 m, 40 m) can be measured with sufficient precision (Altmann, 2015; Altmann, 2017; Haugen, Tønnessen, Svendsen, & Seiler, 2014). However, little is known about single beam systems' validity in capturing interval sprinting times and corresponding velocities, and these studies used differing approaches (Roe et al., 2017) and objectives (Bond, Willaert, & Noonan, 2017; Haugen et al., 2014). In particular, the effect of different timing light heights on measurement accuracy has not been investigated to date.

Therefore, the purpose of the present study was to analyze the accuracy of single beam timing lights at two different heights in determining sprint velocities on the basis of high-speed cameras. Based on the results of this study recommendations could be given for coaches and researchers whether these systems can be employed for determining velocities during linear sprints. We hypothesized that both timing light heights would be able to capture sprint velocities with a sufficient accuracy.

## MATERIALS AND METHODS

### *Study Design*

For the purpose of this study, selected raw data of a previous published study (Altmann, 2017) were used. While the latter study focused on split (5 m and 10 m) and total times during 30-m sprints, the present research addressed the velocities reached in the last sprinting interval (10–30 m, representing a flying 20-m sprint), which have not been investigated to date.

In this cross-sectional experimental laboratory study 15 male sports students performed flying 20-m sprints with a 10-m acceleration phase of maximum effort. The velocities were simultaneously determined by two sets of identical single beam timing lights at a height of 64 cm ($TL_{64}$) and 100 cm ($TL_{100}$), respectively. High-speed cameras served as a reference.

### *Subjects*

Fifteen healthy and physically active male subjects (age, 24.3 ± 1.8 years; age range, 20–27 years; height, 178.5 ± 7.4 cm; body mass, 74.6 ± 8.7 kg) with team-sport background participated in this study. The study was approved from full ethics review by the institutional review board and was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013). Prior to participation, all subjects gave their written informed consent.

***Procedures***
A detailed description of the methods can be found in Altmann (2017). As only selected parameters of the mentioned study were used, merely the acquisition of the data analyzed for the present study is described in the following.

Two sets of single beam timing lights (TAG Heuer, La-Chaux-de-Fonds, Switzerland) were placed in a distance of 10 m and 30 m from a start line. The first set ($TL_{64}$) was placed at a height of 64 cm, matching approx. participants' knee height. With regard to the second set ($TL_{100}$), the timing lights were mounted at 100 cm, matching approx. hip height. These heights were chosen because knee (Cronin & Templeton, 2008; Shalfawi, Enoksen, Tønnessen, & Ingebrigtsen, 2012) and hip height (Sawczuk et al., 2017; Yeadon, Kato, & Kerwin, 1999) are commonly employed in literature, allowing for the findings of the present study to be transferred to other research in terms of measurement set-up.

Behind each timing gate, high-speed cameras (Weinberger Deutschland GmbH, Erlangen, Germany; 100 frames per second) were positioned to track a reflective marker on subjects' right hip representing the body close to the height of the center of mass to provide a reference value of sprinting times.

Following a standardized warm-up protocol and a familiarization trial, athletes performed three flying 20-m sprints with a 10-m acceleration phase and 2 min recovery between trials. To avoid an early deceleration, participants had to sprint as fast as possible past a cone placed 1.50 m behind the finish timing gate. The tests took place indoors on a PVC running surface.

***Data Analysis***
The time intervals between the timing gates positioned at 10 m and 30 m were automatically generated via the timing light software. By determining the measurement accuracy of the timing lights through the video sequences, the times of the reference system (high-speed cameras) were calculated (Altmann, 2017). Subsequently the times captured by all systems were transformed into velocities (m/s).

The mean values of all flying 20-m trials for all systems were used for analysis (Al Haddad, Simpson, & Buchheit, 2015).

***Statistical Analysis***
The data were analyzed using SPSS statistical software version 24.0 (SPSS, Inc., Chicago, IL).

Mean values and standard deviations (SD) of all flying 20-m trials for all systems were calculated for the whole sample.

A one-way repeated measure analysis of variance (ANOVA) was run to detect differences in sprint velocities between $TL_{64}$, $TL_{100}$, and the reference system. Bland & Altman's 95 % limits of agreement (LOA), ICC, and Pearson correlation coefficients were used as additional measures of validity (Atkinson & Nevill, 1998; Bland & Altman, 1999).

Relative between-trial reliability was checked using ANOVA, and intraclass correlation coefficients (ICC; absolute agreement, single measures). Absolute reliability was assessed through root mean square errors (RMSE).

 

For the applied statistical procedures normal distribution as an assumption was given. The significance level for all statistical tests was set a priori to 0.05.

To determine the usefulness, which describes the sensitivity of a test to measure meaningful changes in performance, for all systems the typical error (TE) and the smallest worthwhile change (SWC) were computed. While the TE is expressed as a coefficient of variation (CV) and raw data TE over three trials, the SWC corresponds to the between-subject SD of the mean over these three trials multiplied by 0.2. The calculation of the SWC is based on Cohen's effect size principle, where 0.2 is a typical small effect. The usefulness of the test was then assessed by comparing the TE with the SWC. A TE smaller than the SWC was rated as "good", a TE similar to the SWC as "OK" and a TE larger than the SWC as "marginal" (Hopkins, 2004).

## RESULTS

Descriptive statistics of sprint velocities and reliability measures (ANOVA, CV, ICC, and RMSE) for each system are presented in Table 1.

Table 1. Mean values ± SD of three trials of flying 20-m sprints and corresponding ANOVA, ICC, RMSE, CV, TE, SWC, and Test rating.

| Parameter | Reference | $TL_{64}$ | $TL_{100}$ |
|---|---|---|---|
| **Velocity flying 20-m sprint ± SD [m/s]** | 7.994 ± 0.249 | 7.964 ± 0.262 | 7.940 ± 0.255 |
| **ANOVA [*p*-value]** | 0.931 | 0.742 | 0.710 |
| **ICC [*r*]** | 0.935 | 0.894 | 0.887 |
| **RMSE [m/s]** | <0.001 | 0.107 | 0.124 |
| **CV [%]** | 0.552 | 0.772 | 0.753 |
| **TE [m/s]** | 0.044 | 0.061 | 0.060 |
| **SWC [m/s]** | 0.050 | 0.052 | 0.051 |
| **Test rating** | OK | OK | OK |

*Reference – High-speed video analysis; TL64 – 64 cm; TL100 – 100 cm; SD – Standard deviation; ANOVA – Analysis of variance; ICC – Intraclass correlation coefficient; RMSE – Root mean square error; CV – Coefficient of variation; TE – Typical error of measurement; SWC – Smallest worthwhile change.*

Comparisons between the systems (ANOVA) and validity measures (LOA, ICC, and Pearson's r) can be found in Table 2.

Table 2. ANOVA between all systems and pairwise comparisons (Bonferroni corrected p-values), LOA, ICC and Pearson's r for mean values of three trials of flying 20-m sprints.

| Parameter | Overall | $TL_{64}$ vs. Reference | $TL_{100}$ vs. Reference | $TL_{64}$ vs. $TL_{100}$ |
|---|---|---|---|---|
| **ANOVA [*p*]** | 0.001 | 0.076 | 0.001 | 0.157 |
| **LOA (95 %) [m/s]** | - | -0.060 – 0.120 | -0.013 – 0.121 | - |
| **ICC [*r*]** | 0.977 | 0.978 | 0.969 | 0.982 |
| **Pearson's *r*** | - | 0.985 | 0.991 | 0.986 |

*Reference – High-speed video analysis; TL64 – 64 cm; TL100 – 100 cm; ANOVA – Analysis of variance; LOA (95 %) – Bland & Altman's 95 % limits of agreement; ICC – Intraclass correlation coefficient.*

## DISCUSSION

The aim of the present study was to investigate the accuracy of single beam timing lights at different heights for determining velocities during a flying 20-m sprint.

ANOVA revealed velocities captured by $TL_{100}$ to be significantly slower ($p<0.001$) than by the reference system (high-speed cameras) and a trend ($p=0.076$) for $TL_{64}$ to measure slower velocities than the reference, while there was no difference between the two sets of timing lights (Table 2). However, as the difference between the systems was only approx. 0.4 % (relative) and 0.03 m/s (absolute), the differing results by ANOVA have a limited practical relevance.

In contrast, ICC and Pearson's r values were almost perfect for both timing light heights with regard to the reference, pointing out a high accuracy of measurement (Table 2). These results are supported by low LOA (95 %), indicating low systematic and unsystematic errors. Although LOA of $TL_{100}$ (-0.013–0.121 m/s) were somewhat smaller than LOA of $TL_{64}$ (-0.060–0.120 m/s), both heights could detect performance improvements associated with specific sprint training interventions (Rumpf et al., 2016).

Compared to previous findings (Altmann, 2017; Cronin & Templeton, 2008), the similarity of both heights is a novelty and seems to be counterintuitive at first sight. The similarity of $TL_{64}$ and $TL_{100}$ is likely due to the fact that the running velocities in this study were not dependent from a timing light's accuracy at the start of the acceleration phase, which is associated with the largest measurement error and notable differences between different heights (Altmann, 2017).

The high accuracy of both timing light heights in relation to the reference system in the present study can be explained in two ways.

Firstly, there was a relatively large separation (20 m) between the timing lights. A large separation minimizes the measurement errors in relation to the interval times and therefore improves relative accuracy (Yeadon et al., 1999). Secondly, the larger the running distance, the lower the impact of measurement errors due to swinging arms or legs. In this context, studies by Altmann (2015; 2017) demonstrated measurement errors to continuously decrease from the start to 5 m, 10 m, and 30 m timing lights. Combined with a more upright body position at greater distances (Bond et al., 2017; Haugen et al., 2014), timing lights at both heights (64 cm and 100 cm) were able to determine velocities during the flying 20-m sprint with a 10 m acceleration phase accurately.

In a previous study, Haugen et al.(2014) found that there is no time difference between single and dual beam timing systems in the interval of 20–40 m during a 40-m sprint. Moreover, Bond et al. (2017) reported a non-significant time difference of 0.01 s for an interval of 30–60 feet (9.14–18.29 m) between single beam timing lights (height: 91 cm) and a high-speed video recording. In line with the present research, these studies demonstrate the accuracy of measuring sprint intervals of distances between approximately 10–40 m with the help of single beam timing lights.

A high accuracy of single beam timing lights for assessing maximal running velocities during a 40-m sprint in elite rugby players was previously shown by Roe et al. (2017). The exact timing light height was not reported, however. The significance of this result seems further questionable, since authors used a radar system as a reference method. Actually, in several other studies radar systems were validated via timing lights.

Interestingly, single beam timing lights have been used for validating other technologies such as global positioning systems (GPS) (Castellano, Casamichana, Calleja-González, Román, & Ostojic, 2011; Portas, Rush, Barnes, & Batterham, 2007; Waldron, Worsfold, Twist, & Lamb, 2011) as well as radar guns and laser systems (Berthoin, Dupont, Mary, & Gerbeaux, 2001; Ferro, Floría, Villacieros, & Aguado-Gómez, 2012; Morin, Jeannin, Chevallier, & Belli, 2006; Samozino et al., 2016) in several recent studies, despite the validity of timing lights itself for capturing running velocities was unknown. However, with the here presented results, at least considering high velocities (e. g., 8 m/s), it seems justified to employ single beam timing lights as a reference system.

The between-trial reliability of running velocities over three trials was also considered in this study. Accordingly, both the two sets of timing lights and the reference system showed a high relative (ANOVA, ICC) and absolute (RMSE) reliability. However, as expected, the reference system showed somewhat better values in all reliability measures, with $TL_{64}$ und $TL_{100}$ indicating similar reliability (Table 1).

In the present investigation, the usefulness of all three systems were rated as “OK” as the TE (noise) was similar to the SWC (signal). Therefore, all systems might detect performance changes following a training period. The relatively small between-subject SD compared to other studies assessing high or maximum velocities (Djaoui, Chamari, Owen, & Dellal, 2017; Roe et al., 2017) suggests a high homogeneity of the athletes in the current study. This in turn leads to a low SWC and a usefulness rating of “OK”. A more heterogeneous group with a greater SD and similar TE would probably result in a higher test rating (“good”) (Düking, Born, & Sperlich, 2016; Lockie, Schultz, Callaghan, Jeffriess, & Berry, 2013).

As the sample of this study consisted of young males with a team-sport background, the transferability of the results to other populations remains to be investigated.

## CONCLUSIONS

In conclusion, this research adds further knowledge into the accuracy of single beam timing lights during sprint testing. While the accuracy over short and longer distances (5–30 m) has already been investigated (Altmann, 2015; Altmann, 2017), this study addressed the velocities during flying 20-m sprints with a 10-m acceleration phase using high-speed video cameras as a reference.

Accordingly, single beam timing lights at both heights (64 cm and 100 cm) can be recommended to accurately and reliably determine running speeds during flying 20-m sprints with an acceleration phase of 10 m. Furthermore, both set-ups provide sensitive measures to track changes in athletic performance following a training period. This is in particular of interest for both coaches (e. g., monitoring sprint velocity at a certain time of a season) and researchers (e. g., evaluating the efficacy of a specific training program).

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