ESTIMATING STEP PARAMETERS USING PHOTOELECTRIC CELLS

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The purpose of this study was to assess the OptoJump™ photocell system (Microgate, Bolzano, Italy) in measuring step length and ground contact time during running. In two separate investigations, eight individuals repeatedly ran through a three metre section of OptoJump™ track. Ground contact times were compared to concurrent force platform measures whereas step lengths were compared to physically measured lengths from foot imprints left in powder. Estimates of step length showed excellent validity with only 0.4% difference between methods and an intraclass correlation coefficient of 0.999. The OptoJump™ systematically overestimated contact time with a mean bias of 2.7% compared to force platform measures. These results suggest that the OptoJump™ can be effectively used to estimate step characteristics in real time.

KEY WORDS: OptoJump™, force platform, step length, ground contact time.

INTRODUCTION: The assessment of an athlete's step characteristics is extremely important to both biomechanists and coaches. Performance in running events is determined by an athlete's horizontal velocity which is the product of step length and step frequency (Hay, 1994). Step frequency is calculated as one divided by the total time to complete a step i.e. contact time plus flight time. For this reason the accurate measurement of step parameters is crucial. Previous methods of assessing step lengths, contact times and flight times have included the use of 2D and 3D motion analysis and the use of force platforms (Hunter, Marshall, & McNair, 2004). The accuracy of these methods relies on careful calibration of equipment confined to a laboratory, with the analysis of data generally being quite time consuming. A more simplistic yet highly accurate way of estimating step length has been the footfall imprint method. This involves measuring the distance between the trace left by an athlete's shoe during consecutive ground contacts and has been successfully used in research examining the step lengths during the approach of a long jump (Montagne, Cornus, Glize, Quaine, & Laurent, 2000). Errors in step length estimation from this method arise only from the physical measurement of the distance between imprints and potentially from the foot slipping forward slightly on ground contact. A method or device that can deliver accurate feedback in real time is certainly in demand in sports biomechanics. A recent pilot study by Healy, Howard, Kenny and Harrison (2014) reported that the infrared OptoJump™ system of photoelectric cells could estimate contact time during a drop jump in real time to within ~5 ms of that calculated by a force platform. It is currently not known whether this is the case in running. Glazier and Irwin (2001) evaluated the OptoJump™ to assess step lengths in sprint running. They concluded that the OptoJump™ lacked sufficient validity to estimate step lengths for the purposes of motor control research as random error between the device and three dimensional videography could be as high as 2.7cm. That research used the 32 light emitting diode (LED) OptoJump™ system whereas the current OptoJump™ system contains 96 LEDs per metre thus improving spatial resolution to approximately 1.04 cm. The improved OptoJump™ system has yet to be evaluated against currently acceptable methods of estimating step length. The aim of this preliminary study therefore, was to evaluate the validity of the 96 LED OptoJump™ system to assess step lengths and ground contact times during running.

METHODS: Following ethical approval by the local University Research Ethics Committee eight recreational runners (n=5) and sprinters (n=3) were recruited for this study. Four male participants; age: 24.3 ± 2.9 years; height; 1.80 ± 0.06 m; body mass 77.6 ± 8.5 kg and four female participants; age: 23.5 ± 3.1 years; height; 1.68 ± 0.06 m; body mass 65.2 ± 7.5 kg took part and were free from injury at the time of testing. To estimate ground contact time three metres of OptoJump™ photoelectric cells (Microgate, Bolzano, Italy) were set up alongside an AMTI OR6-5 force platform operating at 1,000 Hz so that foot contacts could be measured by both devices concurrently. To estimate step length a separate investigation was performed whereby the OptoJump™ system was set up on top of a mat which was covered in talcum powder. In both investigations participants performed 10-12 trials running at a submaximal pace over a distance of 20 m with a total of 43 step lengths and 48 contact times recorded. Contact times were obtained directly from the force platform data. Step lengths were measured using a standard steel measuring tape by calculating the displacement between two consecutive foot imprints that were left as result of the participants running over the powder. The posterior most aspect of the foot imprints i.e. the back of the heel were used as the measuring points with the investigator ensuring that participants ran with a heel toe action for all trials. Contact times and step lengths were automatically output by the OptoJump™ proprietary software (OptoJump™ Next software, version 1.9.9.0). Estimates of step length and ground contact time were compared using Bland-Altman 95% limits of agreement (LOA) (Bland & Altman, 1986) and intraclass correlation coefficients (ICCs) with 95% confidence intervals (CI) (Atkinson & Nevill, 1998).

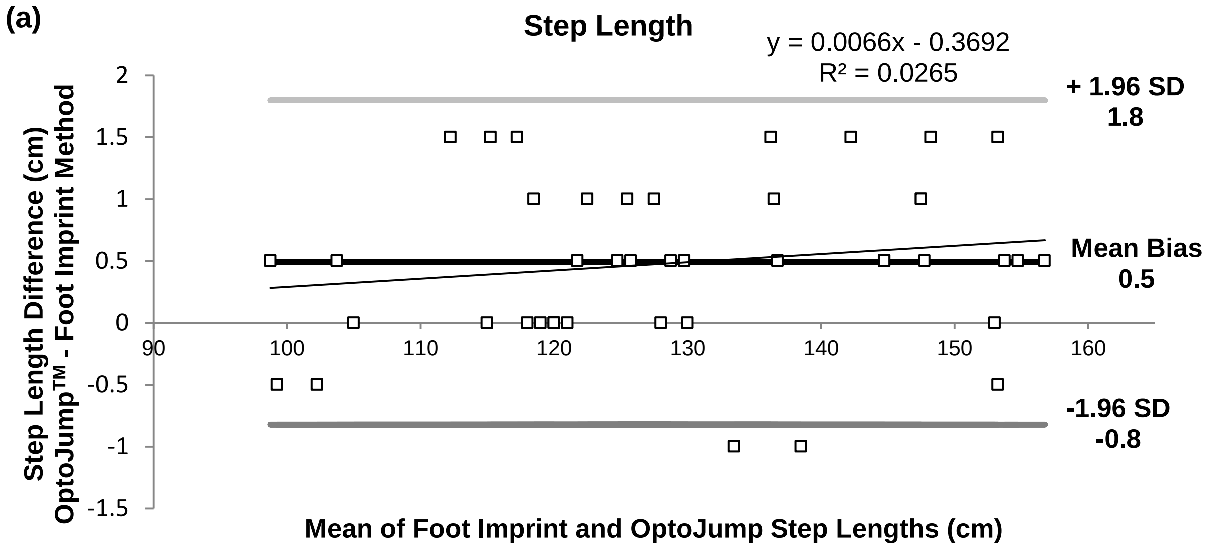
RESULTS: The mean results ± SD with 95% confidence intervals (CI) for step length and ground contact time are given in Tables 1 and 2 respectively. Between method ICCs were 0.999 for step lengths and 0.963 for contact times. Mean bias ± 95% LOA are shown in Tables 1 and 2 with Bland-Altman plots for step length and contact time illustrated in Figure 1.

Table 1: Comparison of step length estimates from the foot imprint method and OptoJump™.

Step Length	
OptoJump™ Mean ± SD (95% CI) cm	130.0 ± 16.5 (124.9-135.1)
Foot Imprint Method Mean ± SD (95% CI) cm	129.5 ± 16.4 (124.4-134.5)
Mean Bias ± 95% LOA cm	0.5 ± 1.3
Mean Bias ± 95% LOA %	0.4 ± 1.0
ICC (95% CI)	0.999 (0.995-0.999)

Table 2: Comparison of ground contact time estimates from the force platform and OptoJump™.

Contact Time	
OptoJump™ Mean ± SD (95% CI) s	0.190 ± 0.020 (0.184-0.195)
Force Platform Mean ± SD (95% CI) s	0.184 ± 0.020 (0.178-0.190)
Mean Bias ± 95% LOA s	0.005 ± 0.004
Mean Bias ± 95% LOA %	2.7 ± 2.2
ICC (95% CI)	0.962 (0.933-0.968)



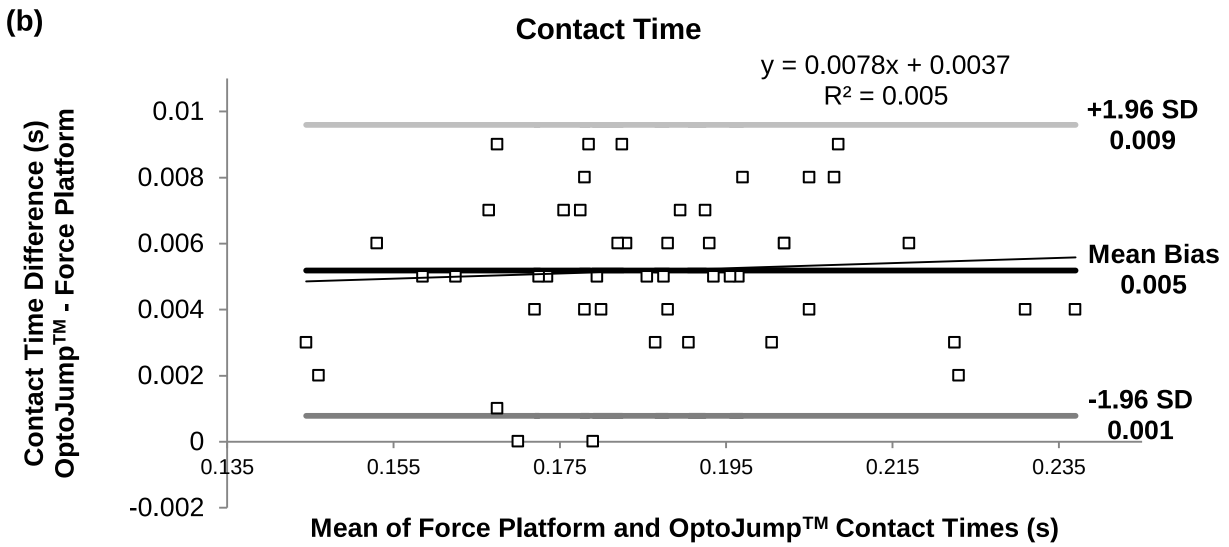


Figure 1: Bland and Altman plots of step length measured by foot imprint method against OptoJump™ (n=43) (a) and contact time measured by force platform against OptoJump™ (n=48) (b).

DISCUSSION: The findings of this study indicate that the OptoJump™ demonstrated excellent validity in the estimation of step length with an ICC of 0.999 and an average overestimation of only 0.5 ± 1.3 cm or 0.4 ± 1% compared to the foot imprint method. This minor overestimation can be explained by the 1.04 cm spatial resolution of the OptoJump™ as step length is calculated based on the nearest LED that is positioned behind the heel. This could result in step length being either "rounded" up or down to the nearest 1 cm which makes a maximum difference of ± 2 cm possible for any given step length. This is likely the reason why the 32 LED OptoJump™ assessed by Glazier and Irwin (2001) was found to have insufficient validity as the spatial resolution was ~3.12 cm thus increasing the maximum potential error. In agreement with the findings of Healy et al., (2014) the OptoJump™ had an ICC of 0.962 with force platform measures and overestimated ground contact time by an average magnitude of 0.005 ± 0.004 s or 2.7 ± 2.2% when compared. The trend lines shown in the bland-altman plots in Figure 1 indicate a slope very close to zero which suggests that the error in the estimation of step length and contact time is independent of the magnitude. This is due to the positioning of the OptoJump™ transmitter LEDs 0.3cm off of the ground. This results in the early detection of contact time and the late detection of flight time thus creating an overestimation in contact time and underestimation in flight time. It is possible that this slight overestimation in contact time cancels out the subsequent underestimation in flight time. This would result in zero error in the estimation of step frequency (as step frequency is calculated using the combined value of contact time and flight time) compared to the force platform however this remains to be seen as flight time was not calculated in the present investigation.

CONCLUSION: The positioning of the 96 LEDs in the OptoJump™ is responsible for the slight overestimation of step length and ground contact time. The excellent validity demonstrated by the OptoJump™ suggests that the portable device can be used with confidence by coaches and researchers in both a field and laboratory environment to measure step characteristics in running in real time.

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Acknowledgement

The authors would like to thank the Irish Research Council for supporting this research.