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Validity and reliability of a robotic sprint resistance device

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Abstract

An increasing number of sprint-related studies have employed robotic devices to provide resistance while sprinting. The aim of this study was to establish within-session reliability and criterion validity of sprint times obtained from a robotic resistance device. Seventeen elite female handball players (22.9 ± 3.0 y; 176.5 ± 6.5 cm; 72.7 ± 5.5 kg; training volume 9.3 ± 0.7 hrs per week) performed two 30-m sprints under three different resistance loading conditions (50, 80 and 110 N). Sprint times ($t_{0\text{-}5m}$, $t_{5\text{-}10m}$, $t_{10\text{-}15m}$, $t_{15\text{-}20m}$, $t_{20\text{-}30m}$ and $t_{0\text{-}30m}$) were assessed simultaneously by a 1080 Sprint robotic resistance device and a post-processing timing system. The results showed that 1080 Sprint timing was equivalent to the post-processing timing system within the limits of precision (± 0.01 s). A systematic bias of ~ 0.34 ± 0.01 s was observed for $t_{0\text{-}5m}$ caused by different athlete location and velocity at triggering point between the systems. Coefficient of variation was ~ 2% for $t_{0\text{-}5}$ and ~ 1% for the other time intervals, while standard error of measurement ranged from 0.01 to 0.05 s, depending on distance and phase of sprint. Intraclass correlation ranged from 0.86 to 0.95. In conclusion, the present study shows that the 1080 Sprint is valid and reliable for sprint performance monitoring purposes.

Key words: Spatiotemporal measurements; sprint conditioning; photocells; resisted sprinting.

INTRODUCTION

Sprint training and testing are common routines for many athletes and coaches. Such practices are accompanied by a variety of modalities (e.g., linear or change-of-direction sprints, accelerated or maximal velocity sprinting), loading components (duration, intensity, resting periods, session rate, resisted/assisted conditions, etc.), procedures (e.g., time initiation and starting position) and equipment (timing gates, laser guns and radar devices, GPS, sleds, towing cords, footwear, etc.) (3, 4).

An increasing number of sprint-related studies have employed robotic devices to provide resistance while sprinting, with the 1080 Sprint (1080 Motion AB, Stockholm, Sweden) commonly used (1, 7-9, 11). Application of such a device may serve several benefits. Firstly, an accurate resistance can be predetermined, which is more challenging with e.g. sleds due to surface friction issues under varying environmental conditions. Moreover, synchronized assessments of velocity and displacement relative to the start line with the force exerted through the machine's cord under varying loading conditions can be obtained by one device only. This will negate the need for the combination of sleds with photocells, laser guns or radars. The distance-time or velocity-time running data can in turn be used for computation of macroscopic mechanical outputs (10) that may form basis for individual training prescription (1, 9, 10). However, these potential benefits are dependent on the ability of the robotic device to accurately assess velocity-time data. To the best of our knowledge, no studies to date have addressed this issue. The purpose of this study was therefore to determine within-session reliability and criterion validity of sprint split times obtained from a 1080 Sprint robotic device.

METHODS

Experimental approach to the problem

The data used for this reliability and validation study were compiled from anonymized data from a previously published investigation exploring the effect of individual sprint training prescription based on force-velocity (FV) profiles (9). Because it is crucial that the entire acceleration phase of sprinting athletes is covered by timing gates to ensure valid and reliable FV profiles (10), the female elite team sport athletes performed 30-m sprints with varying resistance loading. Split times ($t_{0\text{-}5m}$, $t_{5\text{-}10m}$, $t_{10\text{-}15m}$, $t_{15\text{-}20m}$, $t_{20\text{-}30m}$ and $t_{0\text{-}30m}$) were assessed simultaneously by a robotic resistance device and a post-processing timing system. These measurements formed basis for intra-session reliability and validity assessments.

Subjects

Seventeen elite female handball players (mean ± SD: 22.9 ± 3.0 years; 176.5 ± 6.5 cm; 72.7 ± 5.5 kg; total training volume 9.3 ± 0.7 hrs per week) with a minimum of 10-y handball-specific conditioning volunteered to participate. Four of these played for the national team while eleven players participated in the Champions League tournament during the current season. The study was reviewed by the Regional Ethics Committee and approved by the Norwegian Data Protection Authority. Due to the newly implemented General Data Protection Regulations (GDPR) by the European Union, the local university XXXX XXXX XXXX XXXX has the responsibility for data security and ethics. All participants signed an informed consent form prior to participation, and this study was conducted according to the Declaration of Helsinki.

Procedures

A standardized 20-min warm-up consisting of jogging (~60–75% of age-predicted maximal heart rate), selected exercises (lunges, hip lift, ballistic mobility hamstrings and hips in prone and supine), running drills (high knees, skipping, butt-kicks, straight leg pulls) and three to four sprints with increasing speed was conducted prior to testing (9). After the warm-up, the athletes

performed two maximal 30-m sprints with 50, 80 and 110 N resistance respectively, in a randomized order (i.e., one sprint with each resistance before proceeding to the next sequence). The resistance during the six sprints was provided by a 1080 Sprint robotic device (1080 Motion AB, Stockholm, Sweden). All sprints were initiated from a standing, split-stance position with the tip of the toe of the front foot placed on the start line. All starts were commenced from a static position, meaning that "leaning backward before rolling forward" was not allowed. After a ready signal was given by the test leader, the athletes started on their own initiative. Recovery time between each sprint was ~ 4 min.

MuscleLab timing system (Ergotest AS, Porsgrunn, Norway) was used to assess sprint times. An infrared optical contact mat covered the start line, and timing was initiated at the point of front foot lift-off. Post-processing timing gates (i.e., an internal software scans all signals from the timing gate in terms of frequency and duration) where mounted on tripods 120 cm above floor level and placed at 5, 10, 15, 20 and 30 m. Thus, all timing gates were mounted above hip height to avoid undue beam break caused by the lower limbs (3). The onset of the longest break of the infrared beam was used as a trigger criterion, as the torso will produce a longer break than an arm (3). Earp & Newton reported that the signal processing technology completely removed all false signals (i.e., time triggering caused by swinging limbs) (2). Moreover, Rakovic et al. reported excellent reliability values for this system setup, as typical error (TE) and coefficient of variation (CV) were 0.03 s and 1.0% for 0–30 m sprint time and 0.08 $m \cdot s^{-1}$ and 1.4% for V_0 (9). Hence, the MuscleLab timing system was used as gold standard for sprint performance assessments in this study.

The 1080 Sprint was used to provide resistance and assess sprint times. This portable system uses a servo motor (2000 RPM OMRON G5 Series Motor, OMRON Corporation, Kyoto, Japan) to provide resistance while sprinting. The robotic device was placed 5 m behind the starting line with the line attached to the athlete by a centrally located ring (sacrum) on a belt

firmly tightened around the pelvis. The resistance load (50, 80 or 110 N) was determined and controlled by the computer application (1080 Motion, Lidingö, Sweden). The isotonic resistance mode was used, as different modes are offered by the 1080 Sprint. Position trigger criterion for time initiation was set to 30 cm of line being pulled away from the machine. This corresponds to the position of the pelvis being ~ 30 cm past the start line. Data (force, position and time) were recorded at 333 Hz.

Statistical analysis

Mean and standard deviation are presented for all sprint times. Shapiro-Wilk test was used to test the assumption of normality for each set of sprint time data, and z-scores were calculated and analyzed for both skewness and kurtosis. Intraclass correlation coefficient (ICC), standard error of measurement (SEM) and coefficient of variation (CV) were calculated for all sprint-time intervals to determine within session reliability. Criterion validity was based on mean difference (t_{diff}), CV and Pearson's *r* correlation. Spearman's rank correlation was used instead of Pearson's *r* where the datasets were not normally distributed. Bland Altman plots were created for sprint-time difference distribution between the timing systems.

RESULTS

****Table 1 about here****

****Figure 1 about here****

Table 1 shows within session reliability and criterion validity for 1080 Sprint. Regarding reliability, CV ranged from 1.93 to 2.56% for t_{0-5} and from 0.82 to 1.34 for the other time intervals, while SEM ranged from 0.01 to 0.05, depending on distance and phase of sprint. ICC ranged from 0.86 to 0.95.

Distribution of sprint time differences for all resisted sprints are presented in Figure 1. Biases (t_{diff}) where low for $t_{5\text{-}10m}$, $t_{10\text{-}15m}$, $t_{15\text{-}20m}$ and $t_{20\text{-}30m}$ (range = -0.01 to 0.01 s) for all resistance conditions. Greater differences were observed for $t_{0\text{-}5m}$ (range = 0.33 to 0.35 s) and $t_{0\text{-}30m}$ (range = 0.31 to 0.34 s) across all resistance conditions.

DISCUSSION

The aim of the present study was to explore within session reliability and criterion validity of sprint split times obtained from a robotic device during resisted sprinting. Overall, the 1080 Sprint device displayed satisfactory reliability values. The reliability values observed are comparable to previously validated and commonly used timing systems (3). The poorest values were observed for $t_{0\text{-}5m}$. This is in line with Haugen & Buchheit (3), who reported considerably poorer reliability (typical error) for $t_{0\text{-}5m}$ compared to longer sprint-distance intervals.

The current analysis revealed no systematic variation between the 1080 Sprint and the post-processing timing gates, except for $t_{0\text{-}5m}$ and $t_{0\text{-}30m}$. That is, for practical purposes these systems give similar results to a precision of ± 0.01 s. Post-processing timing gates, which were used as gold-standard in this case, are considered accurate for sprint performance monitoring, as the internal software processes and remove false signals (3). This provides that the timing gates are mounted above hip height (to avoid undue beam break caused by the lower limbs), as performed in this study. However, a systematic bias of ~ 0.34 ± 0.01 s was observed for $t_{0\text{-}5m}$ and $t_{0\text{-}30m}$. This is not surprising, as the starting method and timing system used can combine to generate large absolute differences in "sprint time" (3, 6). The sources of time differences usually include the starting device, vertical and horizontal placement of starting device relative to the start line, body configuration and velocity at triggering point (6). In this case, pelvis was ~ 60 cm past the start line at time initiation for the optical contact mat (front foot lift-off), while only ~ 30 cm past the start line at time initiation for the robotic device. Hence, pelvis was ~ 30

cm further past the start line at time initiation for the optical contact mat than for the robotic device. Provided that the bias is systematic so that correction factors can be generated (as in this case), sprint performance comparisons across systems can be performed (3). The same issue is present for calculation of sprint mechanical outputs based on distance-time or speed-time data. An essential point when using the simple method proposed by Samozino et al. (10) is that the time 0 must be very close to the first rise of the force production onto the ground. This is equivalent to a setup with starts from blocks and audio signal with reaction time subtracted from the total time (5). According to Haugen & Buchheit (3), front-foot triggering generates 0.51 s faster sprint times compared to starts from blocks where reaction time is subtracted from the total time. Because the current systematic bias was 0.34 s on average (Table 1), we estimate that a correction factor of ~ 0.17 s (i.e., 0.51 minus 0.34 s) should be added to the 1080 Sprint times to ensure valid computations of sprint mechanical outputs.

PRACTICAL APPLICATIONS

The present study shows that the 1080 Sprint is valid and reliable for sprint performance monitoring purposes. This means that multiple functions for sprint training, testing and monitoring can be operated by one device only. The benefits of using one system in both research and field based settings includes i) accurate prescription of resistance while obtaining synchronized assessments of velocity, acceleration and pulling force as a function of time or displacement relative to starting line, ii) the possibility to apply varying resistance loading during specific portions of the sprint, iii) monitor individual and team responses (i.e fatigue) and iiii) computation of sprint mechanical outputs.

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Table 1. Within session reliability and criterion validity for 1080 Sprint

Resistance	Interval	Sprint times (mean ± SD)		Reliability			Criterion validity		
		t_{ML} (s)	t_{1080} (s)	CV (%)	SEM (s)	ICC	t_{diff} (s)	CV (%)	Cor.
50 N	t_{0-5m}	0.97±0.04	1.30 ± 0.05	2.26	0.03	0.81	.329	20.54	0.79
	t_{5-10m}	0.85±0.03	0.85 ± 0.02	1.01	0.01	0.92	.002	1.65	0.75
	t_{10-15m}	0.78±0.02	0.77 ± 0.02	1.06	0.01	0.90	-.008	2.01	0.48
	t_{15-20m}	0.72±0.02	0.73 ± 0.02	1.03	0.01	0.92	.007	1.60	0.73
	t_{20-30m}	1.43±0.04	1.43 ± 0.04	0.82	0.01	0.95	.001	0.74	0.94
	t_{0-30m}	4.75±0.11	5.06 ± 0.12	0.91	0.05	0.93	.308	4.49	0.94
80 N	t_{0-5m}	1.03±0.04	1.36 ± 0.05	1.93	0.02	0.87	.331	19.76	0.57
	t_{5-10m}	0.90±0.03	0.91 ± 0.02	0.99	0.01	0.92	.005	1.37	0.80
	t_{10-15m}	0.83±0.02	0.82 ± 0.02	1.13	0.01	0.89	-.007	1.56	0.71
	t_{15-20m}	0.78±0.02	0.79 ± 0.02	1.34	0.01	0.85	.010	1.50	0.79
	t_{20-30m}	1.55±0.05	1.56 ± 0.04	1.32	0.02	0.89	.005	0.76	0.93
	t_{0-30m}	5.08±0.13	5.41 ± 0.14	1.12	0.04	0.90	.320	5.97	0.94
110 N	t_{0-5m}	1.06±0.05	1.41 ± 0.07	2.56	0.03	0.86	.353	20.49	0.74
	t_{5-10m}	0.96±0.04	0.96 ± 0.02	1.10	0.01	0.90	-.002	1.52	0.82
	t_{10-15m}	0.89±0.02	0.88 ± 0.02	1.01	0.01	0.92	-.006	1.54	0.68
	t_{15-20m}	0.85±0.03	0.86 ± 0.02	0.98	0.01	0.94	.012	1.86	0.83
	t_{20-30m}	1.70±0.05	1.71 ± 0.05	1.30	0.02	0.91	.004	0.87	0.92
	t_{0-30m}	5.45±0.15	5.79 ± 0.16	1.10	0.04	0.92	.338	4.29	0.95

t_{ML} = sprint times from the MuscleLab timing system, t_{1080} = sprint times from the 1080 Sprint robotic device, CV = coefficient of variation, SEM = standard error of measurement, ICC = intraclass correlation coefficient, t_{diff} = time difference between the analyzed systems, Cor. = Correlation (Pearsons r or Spearman's rank).

Figure 1. Bland Altman analysis of sprint times (34 trials for each resisted condition) derived from timing gates and 1080 Sprint.