The Reliability and Validity of Short-Distance Sprint Performance Assessed on a Nonmotorized Treadmill

Jamie M. Highton, Kevin L. Lamb, Craig Twist, and Ceri Nicholas,

Department of Sport and Exercise Sciences, University of Chester, Chester, United Kingdom

Abstract

Highton, JM, Lamb, KL, Twist, C, and Nicholas, C. The reliability and validity of short-distance sprint performance assessed on a nonmotorized treadmill. *J Strength Cond Res* 26(2): 458–465, 2012—This study examined the interday and intraday reliabilities and validities of various sprint performance variables on a nonmotorized treadmill (NMT) over distances of 10, 20, and 30 m. After habituation, 12 male team-sport players performed 3 sprints on the NMT on 2 separate days and an assessment of overground running performance, separated by 24 hours. Measurements included sprint times, mean and peak sprint speeds, and step length and frequency. Data analysis revealed no significant mean differences ($p > 0.05$) between NMT variables recorded on the same day or between days. Ratio limits of agreement indicated that the best levels of agreement were in 20-m (1.02 ×/÷ 1.09) and 30-m (1.02 ×/÷ 1.07) sprint times, peak (1.00 ×/÷ 1.06) and mean (0.99 ×/÷ 1.07) running speed, and step length (0.99 ×/÷ 1.09) and frequency (1.01 ×/÷ 1.06). The poorest agreement was observed for time to peak running speed (1.10 ×/÷ 1.47). These reliability statements were reinforced by coefficients of variation being <5% for all the variables except time to peak running speed (11%). Significant differences ($p < 0.05$) were observed between NMT and overground sprint times across all distances, with times being lower (faster) by approximately 25–30% overground. The correlations between NMT and overground variables were generally modest (0.44–0.67), and optimal for time to cover 30 m on day 2. Our data support NMT ergometry as a reliable tool for most of the sprint performance variables measured and reveal that the fastest 30-m overground sprinters were likely to be identifiable via NMT ergometry.

Key Words reproducibility, limits of agreement, sprint treadmill, overground sprinting

Address correspondence to Dr. Kevin L. Lamb, k.lamb@chester.ac.uk.

26(2)/458–465

Journal of Strength and Conditioning Research

Introduction

Sprint running performance is considered to be a fundamental component of success in a variety of competitive team or 'multiple-sprint' sports (e.g., soccer, rugby, hockey). Time-motion analysis has shown that on average approximately 20–60 sprints, operationally defined as "maximal effort, a rapid motion" (5), per player per game will take place (26). Mean sprint times and distances in such sports are between 2 and 3 seconds and 10–20 m, respectively (26), with sprints rarely exceeding distances of 40 m (3,21). Consequently, the physiological assessment of team-sport players is often confined to their sprinting performances over distances of 5–40 m (7,19), whether after training interventions (27) or different periods of recovery (12,19).

Nonmotorized treadmill (NMT) ergometry, as originally described by Lakomy (17), provides a potentially useful tool for the assessment of maximal sprint running performance. Its use allows the benefits associated with testing in controlled laboratory conditions and the calculation of many performance measures (e.g., time to peak running speed, step length, and step frequency), which are potentially of interest to athletes and players and their coaches. By using NMT ergometry, these sprint parameters can be measured continually, providing real-time information for coaching or research purposes.

The importance of ensuring that the measurements made as part of research or athlete support are both reliable and valid is widely recognized (1). Such an approach allows us to detect 'real' changes in performance with confidence and ensures that a test or instrument is measuring what it purports to. In recent years, several studies (adopting appropriate statistical tests) have documented the reliability of certain performance (13,14,18,25,28) and physiological (25) variables obtained via NMT ergometry. Such variables include maximal force, maximal power, maximal running speed, heart rate, and oxygen consumption, the reliability of which has generally been interpreted as favorable. However, there are several potentially beneficial performance measurements that can be obtained via NMT ergometry whose reliability is yet to be assessed, including mean speed, split times over multiple distances, and step rate and length. In addition, the statistical agreement between the measures obtained on the NMT over a variety of distances and those obtained overground remains to be elucidated, with only the early work of Lakomy (17), and more recently Hopker et al. (13), offering direct comparisons between performances in each. As such, the potential utility of the NMT for the assessment of sprint performance in team-sport athletes is yet to be fully explored. Accordingly, the purpose of this study was to report on both the interday and intraday reliabilities and concurrent validity of a variety of sprint performance measures obtained on a commercially available NMT over distances commonly associated with team-sport competition.

Methods

Experimental Approach to the Problem

This study used a repeated measures design in which the participants, after a period of familiarization, were required to complete 2 laboratory trials on separate days involving the assessment of NMT sprint performance (to assess the interday reliability of measured variables) and 1 trial on an outdoor all-weather surface for the assessment of overground sprinting performance (Figure 1). The order of sprint assessment was randomized for each participant, with each of the 3 trials separated by 24 hours. On each testing occasion, the participants performed 3 maximal sprints, which in the case of the NMT were used to assess the intraday reliability of values obtained. The participants were instructed to refrain from any strenuous physical activity and maintain their normal diet (avoiding any nutritional supplements) during the period of testing to avoid any possible interference that this might have on their sprinting abilities.

Subjects

Twelve healthy male university level team-sport (soccer, rugby union, and rugby league) players (mean age: 22.3 ± 3.6 years; body mass: 80.3 ± 8.4 kg; stature: 1.8 ± 0.1 m) volunteered to participate in the study. Before data collection, all the participants provided written informed consent and completed a pretest health questionnaire to reveal if there were any contraindications to exercise. The study was also performed in accordance with the ethical standards set forth by Harriss and Atkinson (11), with ethical approval granted by the Ethics Committee of the Department of Sport and Exercise Sciences, University of Chester.

Procedures

Nonmotorized Treadmill Familiarization. The NMT (Woodway, Force 3.0, Waukesha, WI, USA) used in this study was a modernized version of the system originally presented by Lakomy (16,17) and is similar to the systems that have been described in detail in previous studies (e.g., [13,14,25,28]). Approximately 48–72 hours before data collection, the participants were familiarized with the NMT over 3 sessions within a 24-hour period. These sessions provided detailed verbal instructions on the technique required to run on the NMT (which were then reinforced before each sprint performance session) and allowed the participants to walk and then jog at a low intensity before completing 3 sprints for 30 m at gradually increasing speeds (i.e., from ~60–100% of their perceived maximum speeds). The familiarization session was terminated when the participants indicated that they were comfortable to sprint maximally and were achieving a consistent running speed (within 1 $m \cdot s^{-1}$) at each maximal sprint.

Assessment of Nonmotorized Treadmill Sprint Performance. The NMT sprint performance variables were measured after a warm-up on the NMT consisting of 3 minutes continuous jogging interspersed with 1 maximal sprint for 6 seconds (28). This also served to 'warm up' the treadmill rollers and thus minimize the resistance of the treadmill belt (17). During the sprints that followed, the participants were connected to a mounted strain gauge via a nonelastic tether and harness that was attached around their waists. The height of the strain gauge was adjusted so that the tether was at an angle of 8° (measured via a goniometer) above the horizontal for each participant (while standing) so as to maintain the horizontal position of the tether during the forward lean adopted when sprinting on the NMT (17). The participants were instructed to sprint maximally from a standing start on the researcher's instruction and to maintain the effort until they had reached a distance of 30 m. Split times were also recorded at 10 and 20 m, with speed sampled at a rate of 100 Hz. For measurements of peak running speed, data were also

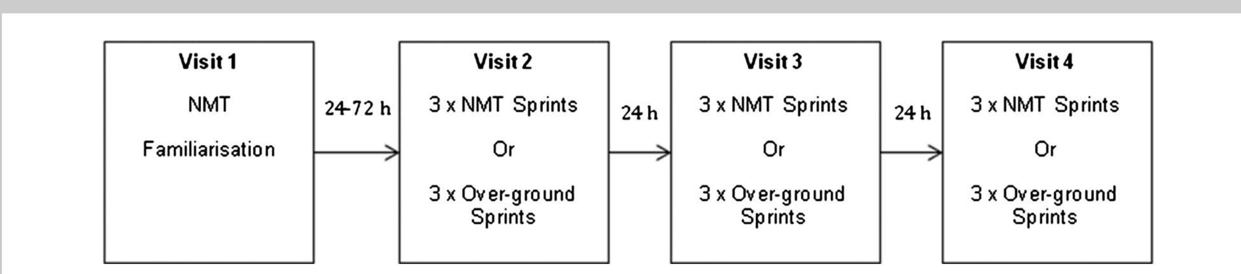

Figure 1. Schematic of the study design.

TABLE 1. Interday NMT descriptive (mean ± *SD*) and reliability statistics.*

Performance variable	Day 1	Day 2	Limits of agreement	Ratio limits of agreement	Coefficient of variation (%)
Time to 10 m (s)	2.39 ± 0.17	2.30 ± 0.22	0.09 ± 0.34	1.04 ×/÷ 1.16	4.2
Time to 20 m (s)	4.23 ± 0.26	4.13 ± 0.25	0.10 ± 0.37	1.02 ×/÷ 1.09	2.8
Time to 30 m (s)	6.10 ± 0.36	6.00 ± 0.3	0.11 ± 0.42	1.02 ×/÷ 1.07	2.2
10–20 m (s)	1.80 ± 0.11	1.82 ± 0.11	0.02 ± 0.14	1.01 ×/÷ 1.08	2.3
20–30 m (s)	1.83 ± 0.11	1.83 ± 0.14	−0.01 ± 0.19	0.99 ×/÷ 1.12	2.9
Peak instantaneous speed ($m\cdot s^{-1}$)	5.62 ± 0.28	5.60 ± 0.26	−0.02 ± 0.35	1.00 ×/÷ 1.06	1.8
Peak averaged speed ($m\cdot s^{-1}$)	5.56 ± 0.28	5.54 ± 0.26	−0.02 ± 0.33	1.00 ×/÷ 1.06	1.8
Mean speed ($m\cdot s^{-1}$)	4.94 ± 0.27	5.02 ± 0.25	−0.08 ± 0.33	0.99 ×/÷ 1.07	2.1
Time to peak speed (s)	3.41 ± 0.73	3.09 ± 0.65	0.32 ± 1.16	1.10 ×/÷ 1.47	10.8
Step length (m·per step)	1.16 ± 0.09	1.16 ± 0.99	−0.01 ± 0.09	0.99 ×/÷ 1.09	2.3
Step frequency ($steps\cdot s^{-1}$)	4.43 ± 0.33	4.48 ± 0.33	0.06 ± 0.25	1.01 ×/÷ 1.06	1.6

*NMT = nonmotorized treadmill.

averaged over 1 second to provide peak measurements and are referred to as 'peak averaged' hereafter. This procedure was repeated twice more interspersed with 2 minutes of passive recovery.

Assessment of Overground Sprint Running Performance. To assess the concurrent validity of sprint performance variables obtained on the NMT, the participants performed 3 maximal 30-m sprints from a standing start on an outdoor all-weather surface, interspersed with a 2-minute passive recovery. Sprints were conducted in dry conditions, with the direction of the sprints being perpendicular to any prevailing wind direction (8,22). Sprint times were recorded using 6 electronic photo cells (Speedtrap II, Brower Timing Systems, UT, USA) positioned at 10, 20, and 30 m from the start line. The initial gate at the start of the sprint was replaced by a switch activated by the participant's foot leaving the ground, which served to reduce the degree of momentum developed before the start of the sprint and prevent extraneous movement influencing the recorded sprint times (6). Sprint times to each of these distances were recorded to the nearest 0.01 second via telemetry to a hand-held system, with the lowest value (i.e., best performance) from the 3 sprints used for data analysis.

Statistical Analyses

The measures obtained from the NMT included 10-, 20-, and 30-m sprint times (seconds), mean and peak (averaged and instantaneous) running speeds (meters per second), time to peak running speed (seconds), step length (meters per step), and step frequency (steps per second). Optimum values (best performances) from the 3 sprints were used in the analysis of

TABLE 2. Intraday NMT descriptive (mean ± *SD*) and reliability statistics (day 1).*

Performance variable	Trial 2	Trial 3	Limits of agreement	Ratio limits of agreement	Coefficient of variation (%)
Time to 10 m (s)	2.48 ± 0.24	2.50 ± 0.24	−0.02 ± 0.33	0.99 ×/÷ 1.14	2.8
Time to 20 m (s)	4.28 ± 0.26	4.34 ± 0.34	−0.06 ± 0.31	0.99 ×/÷ 1.07	1.7
Time to 30 m (s)	6.16 ± 0.36	6.23 ± 0.42	−0.07 ± 0.39	0.99 ×/÷ 1.06	1.8
10–20 m (s)	1.80 ± 0.11	1.85 ± 0.14	−0.04 ± 0.16	1.02 ×/÷ 1.08	1.9
20–30 m (s)	1.88 ± 0.11	1.89 ± 0.13	−0.01 ± 0.22	0.99 ×/÷ 1.13	3
Peak instantaneous speed ($m\cdot s^{-1}$)	5.58 ± 0.26	5.55 ± 0.33	0.03 ± 0.27	1.01 ×/÷ 1.07	1.2
Peak averaged speed ($m\cdot s^{-1}$)	5.52 ± 0.26	5.50 ± 0.33	−0.02 ± 0.26	0.95 ×/÷ 1.05	1.1
Mean speed ($m\cdot s^{-1}$)	4.89 ± 0.26	4.81 ± 0.37	0.08 ± 0.52	1.02 ×/÷ 1.12	2.4
Time to peak speed (s)	3.78 ± 0.75	3.76 ± 0.98	0.02 ± 1.11	1.02 ×/÷ 1.33	8.1
Step length (m·per step)	1.14 ± 0.08	1.13 ± 0.07	−0.01 ± 0.08	0.99 ×/÷ 1.07	1.7
Step frequency ($steps\cdot s^{-1}$)	4.37 ± 0.37	4.43 ± 0.33	0.04 ± 0.23	1.01 ×/÷ 1.05	1.4

*NMT = nonmotorized treadmill.

Table 3. Intraday NMT descriptive (mean ± *SD*) and reliability statistics (day 2).*

Performance variable	Trial 2	Trial 3	Limits of agreement	Ratio limits of agreement	Coefficient of variation (%)
Time to 10 m (s)	2.51 ± 0.34	2.41 ± 0.16	0.10 ± 0.50	1.03 ×/÷ 1.20	5.1
Time to 20 m (s)	4.34 ± 0.39	4.24 ± 0.19	0.10 ± 0.52	1.02 ×/÷ 1.12	3.1
Time to 30 m (s)	6.20 ± 0.44	6.11 ± 0.26	0.09 ± 0.47	1.01 ×/÷ 1.07	2.1
10–20 m (s)	1.83 ± 0.09	1.83 ± 0.09	0.00 ± 0.05	1.00 ×/÷ 1.03	0.7
20–30 m (s)	1.85 ± 0.16	1.87 ± 0.11	−0.02 ± 0.16	0.99 ×/÷ 1.09	1.9
Peak instantaneous speed ($m\cdot s^{-1}$)	5.53 ± 0.27	5.55 ± 0.26	−0.02 ± 0.24	1.00 ×/÷ 1.04	1.2
Peak averaged speed ($m\cdot s^{-1}$)	5.48 ± 0.27	5.50 ± 0.26	0.02 ± 0.21	1.00 ×/÷ 1.04	1.1
Mean speed ($m\cdot s^{-1}$)	4.85 ± 0.35	4.92 ± 0.21	−0.08 ± 0.40	0.98 ×/÷ 1.08	2.3
Time to peak speed (s)	3.65 ± 0.98	3.52 ± 0.88	0.13 ± 1.58	1.03 ×/÷ 1.49	10.8
Step length ($m\cdot step^{-1}$)	1.11 ± 0.08	1.14 ± 0.10	0.04 ± 0.1	1.03 ×/÷ 1.09	2.6
Step frequency ($steps\cdot s^{-1}$)	4.41 ± 0.37	4.37 ± 0.38	−0.05 ± 0.25	0.99 ×/÷ 1.06	1.5

*NMT = nonmotorized treadmill.

concurrent validity against overground sprint performance and interday reliability. Data from trials 2–3 on the same day (because these were typically where the fastest sprints occurred) were used to assess the intraday reliability of the sprint variables. After an examination of the distributions of the variables via the Shapiro-Wilk test of normality, descriptive statistics (mean ± *SD*) were generated. The reliability was assessed via the coefficient of variation and the 95% limits of agreement (LoA; bias ± 1.96 × SD_{diff}) as originally described by Bland and Altman (4). The ratio LoA (see Atkinson and Nevill [1] for a review) were also calculated owing to the presence of heteroscedastic errors among certain residuals (1), which were reduced (and in some cases removed) by applying logarithmic (natural) transformations. The validity of the NMT measures against overground sprinting was examined via correlation analysis (Spearman's rho; r_s as the variables were not always normally distributed) and the 95% and ratio LoA statistics. Alpha was set at 0.05, and all statistical analyses were conducted using SPSS for Windows (Version 14.0, 2006).

Results

The interday reliability statistics of 11 variables measured on the NMT are presented in Table 1. Although there were no significant biases ($p > 0.05$) between the measurements taken on separate days for any of these, the best levels of agreement (within 7%) between days were observed for the measurements of time to 30 m (1.02 ×/÷ 1.07), peak instantaneous (0.99 ×/÷ 1.07), peak averaged (1 ×/÷ 1.06), mean speeds (1 ×/÷ 1.06), and step frequency (1.01 ×/÷ 1.06). Time to peak speed exhibited the poorest agreement, with a difference of up to 47%.

The intraday reliability (day 1) statistics on the NMT (Tables 2 and 3) show no significant biases ($p > 0.05$) for any

Table 4. Concurrent validity statistics for the NMT variables (day 1).*

Performance variable	NMT	Overground	Limits of agreement	Ratio limits of agreement	Coefficient of variation (%)	r_s
Time to 10 m (s)	2.39 ± 0.17	1.70 ± 0.20	−0.68 ± 0.45†	0.71 ×/÷ 1.26	23.9	0.43
Time to 20 m (s)	4.23 ± 0.26	3.01 ± 0.22	−1.22 ± 0.51†	0.71 ×/÷ 1.14	23.8	0.54
Time to 30 m (s)	6.10 ± 0.36	4.23 ± 0.25	−1.88 ± 0.60†	0.69 ×/÷ 1.11	25.7	0.58‡
10–20 m (s)	1.80 ± 0.11	1.30 ± 0.05	−0.50 ± 0.19†	0.72 ×/÷ 1.11	22.8	0.50
20–30 m (s)	1.83 ± 0.11	1.20 ± 0.06	−0.64 ± 0.15†	0.65 ×/÷ 1.08	29.7	0.67‡
Mean speed ($m\cdot s^{-1}$)	4.94 ± 0.27	7.02 ± 0.42	−2.09 ± 0.71†	0.70 ×/÷ 1.12	25.5	0.58‡

*NMT = nonmotorized treadmill.
†$p < 0.05$ reflecting the presence of a systematic bias between measurements.
‡$p < 0.05$ reflecting the presence of a systematic bias between measurements.

Table 5. Concurrent validity statistics of the NMT variables (day 2).*

Performance variable	NMT	Overground	Limits of agreement	Ratio limits of agreement	Coefficient of variation (%)	r_s
Time to 10 m (s)	2.30 ± 0.22	1.70 ± 0.20	−0.60 ± 0.48†	0.74 ×/÷ 1.26	21.2	0.44
Time to 20 m (s)	4.13 ± 0.25	3.01 ± 0.22	−1.12 ± 0.45†	0.73 ×/÷ 1.12	22.1	0.66‡
Time to 30 m (s)	6.00 ± 0.30	4.23 ± 0.25	−1.77 ± 0.47†	0.70 ×/÷ 1.09	24.5	0.80‡
10–20 m (s)	1.82 ± 0.09	1.30 ± 0.05	−0.52 ± 0.16†	0.71 ×/÷ 1.11	23.7	0.30
20–30 m (s)	1.83 ± 0.14	1.20 ± 0.06	−0.63 ± 0.15†	0.65 ×/÷ 1.08	29.4	0.48
Mean speed ($m \cdot s^{-1}$)	5.02 ± 0.25	7.02 ± 0.42	−2.01 ± 0.71†	0.71 ×/÷ 1.12	24.5	0.60‡

*NMT = nonmotorized treadmill.
†$p < 0.05$ reflecting the presence of a systematic bias between measurements.
‡$p < 0.05$ reflecting the presence of a systematic bias between measurements.

Table 6. Reliability of running speeds at 1, 2, and 3 seconds.

Variable ($m \cdot s^{-1}$)	Mean ± *SD*			
Between trials: day 1	Trial 1	Trial 2	Limits of agreement	Ratio limits of agreement
Speed at 1 s	4.06 ± 0.6	4.03 ± 0.60	−0.03 ± 0.93	0.99 ×/÷ 1.28
Speed at 2 s	5.14 ± 0.4	5.2 ± 0.41	0.05 ± 0.41	1.01 ×/÷ 1.08
Speed at 3 s	5.46 ± 0.29	5.42 ± 0.40	−0.03 ± 0.29	0.99 ×/÷ 1.06
Between trials: day 2	Trial 1	Trial 2		
Speed at 1 s	3.93 ± 0.86	4.21 ± 0.44	0.28 ± 1.3	1.09 ×/÷ 1.49
Speed at 2 s	5.16 ± 0.46	5.25 ± 0.28	0.09 ± 0.56	1.02 ×/÷ 1.12
Speed at 3 s	5.47 ± 0.28	5.48 ± 0.28	0.01 ± 0.23	1.00 ×/÷ 1.04
Between days	Day 1	Day 2		
Speed at 1 s	4.24 ± 0.39	4.45 ± 0.53	0.21 ± 0.85	1.05 ×/÷ 1.22
Speed at 2 s	5.28 ± 0.29	5.23 ± 0.31	0.05 ± 0.34	1.01 ×/÷ 1.06
Speed at 3 s	5.49 ± 0.3	5.52 ± 0.27	0.03 ± 0.29	1.01 ×/÷ 1.05

of the measures, and the best agreement (within 7%) occurred for the time to 20 (0.99 ×/÷ 1.07) and 30 m (0.99 ×/÷ 1.06), peak averaged (0.95 ×/÷ 1.05), mean speed (1.01 ×/÷ 1.07) and step length (0.99 ×/÷ 1.07), and frequency (1.01 ×/÷ 1.05). As with measurements taken between days, it was time to peak speed, which demonstrated the poorest agreement between trials (up to 33% difference).

In terms of concurrent validity, all of the performance measures on the NMT were found to be significantly inferior ($p < 0.05$) to those obtained from overground sprinting on both days (Tables 4 and 5). For example, the 30-m split times were, on average, 1.88 (day 1) and 1.77 seconds (day 2) faster overground than on the NMT, and the mean speeds were 2.09 (day 1) and 2.02 $m \cdot s^{-1}$ (day 2) lower. The correlations between NMT and overground variables were typically modest (0.44–0.67), though as high as 0.80 (time to 30 m, day 2) and as low as 0.30 (10- to 20-m time, day 2).

Discussion

This study has demonstrated that particular measures of sprint performance can be generated reliably on the NMT. Specifically, for measurements obtained on the same day, times to 20 and 30 m, peak averaged and mean speed, and step length and frequency demonstrated the best levels of agreement. Similarly, for interday measurements, agreement was the best for times to 30 m, peak instantaneous, peak averaged and mean speeds and step frequency. Although these findings are consistent with those of previous studies that have generally reported that NMT measurements of running speed and distance covered in a set time interval are reliable (13,14,18,25,28), they are unique in that no previous studies have identified step length and frequency measures to be among the most reliable. The implication of this discovery is not trivial considering that the goal of many sprint training programs is to improve either one or both of these kinematic parameters (23,24,27,29). Step length and frequency are typically measured via video analysis, which is often time consuming and will generally preclude the provision of real-time feedback. Based on our findings, it appears that NMT may offer a reliable and time-effective method of assessing sprint kinematics over 30 m.

The acceptability of the measurement error (reliability) observed for the majority of our measures of sprint performance is endorsed when one considers it in the context of whether a future study involving a 'practical' sample size could detect a genuine change in sprint performance (because of an intervention, for instance). The employment of such an 'analytical goal' (1) has seldom been done in studies of this kind, though it adds quality to the interpretation of the reliability data. Previous research has demonstrated that changes in sprint performance, either after training programs or during periods of fatigue or recovery, are usually small, typically falling between 2 and 7% (10,12,15,20,23,24,29). Therefore, given the calculated ratio LoA for our measures, the nomogram of Atkinson et al. (2) reveals that a sample size of approximately 10–30 participants would be required to detect a 5% change in each of these measures. Accordingly, we can posit that the measurement error associated with these is acceptable given that the practical sample size used in this study would be sufficient to detect such a change.

To our knowledge, this study is one of the first of its type to present information on sprint performance over several different distances. Importantly, our data indicate that the reliability of sprint times recorded on the NMT improves as the distance increases, with 10-m sprint times, although still considered reliable based upon the sample size required to detect a meaningful change in this variable (~25 participants), demonstrating the poorest levels of agreement (both between trials on the same day and between days), in comparison to times for 20- and 30-m and the 10- to 20-m and 20- to 30-m split times. A possible explanation for this finding is the relatively high degree of force required to overcome the inertia of the treadmill belt at the start of the sprint compared with running overground. This, combined with the high retarding forces that act on the participant throughout NMT running (17), provides the scope for higher degrees of performance variability in general and particularly at the outset. Moreover, the participant is likely to be more vulnerable to such effects when not habituated to NMT running, fatigued, or lacking in motivation.

Of all the variables reported in this study, it was only time to peak running speed which demonstrated unacceptable levels of intraday and interday levels of agreement. For this variable, a sample size of up to 100 participants would be required to detect a genuine 5% change in performance, whereas the intraday and interday variations were as high as 47%, a value way beyond any expected change in sprint performance associated with either training or fatigue. In addition, the coefficient of variation was >10% (a common, if arbitrary, cut-off point for the assessment of reliability).

Despite the potential utility of time to peak running speed as a marker of an individual's acceleration, no study to date has examined its reliability. However, the fact that our data demonstrated poor levels of both intraday and interday reliabilities would seem to be of little value to coaches and researchers and likely reflects issues with NMT reliability during the early stages of a sprint. In an attempt to counteract this, and to provide a meaningful measure of acceleration, measurements of running speed at fixed time points which corresponded to average sprint durations during team-sport activity (i.e., 1, 2, and 3 seconds) were analyzed for reliability (Table 6). Measurements of running speed at both 2 and 3 seconds demonstrated high levels of intraday (1.02 ×/÷ 1.12 and 1.00 ×/÷ 1.04, respectively) and interday (1.01 ×/÷ 1.06 and 1.01 ×/÷ 1.05, respectively) agreement. However, as with time to 10 m, the values obtained earlier on in the sprint (1 second) demonstrated poor levels of intraday and interday reliabilities (1.09 ×/÷ 1.49 and 1.05 ×/÷ 1.22, respectively). As such, we suggest that the measurements of running speed at 2 and 3 seconds, and not time to peak running speed, may provide more valuable feedback on acceleration during maximal sprint running on the NMT.

With respect to the concurrent validity of the NMT measures against overground running, our observation of the presence of systematic bias for times to 10, 20, and 30 m and mean running speed concur with the findings of the original study of Lakomy (17). That is, our participants were significantly slower on the NMT (25–30% cf., 20%) than when sprinting overground. Similarly, in the only other study making a direct comparison between NMT and overground sprint performance, Hopker et al. (13) reported that 20-m sprint time was significantly higher by approximately 2.59 seconds on the NMT compared with that in running overground. As we allude to the above, this attenuation of performance is probably a consequence of the participants having to overcome the high intrinsic resistance of the NMT belt. In addition, the participant does not reach the inertia characteristic of overground sprint running when the maximal speed is reached on the NMT but instead must constantly accelerate the treadmill belt between steps.

The association between the performance on the NMT and overground running was also generally moderate in this study, with only the correlations for time to 20 and 30 m and mean speed being significant and in excess of 0.58 ($r_s = 0.66$, 0.8, and 0.6, respectively). Nonetheless, the trend for individuals who were faster on the NMT over distances of 20 and 30 m to be faster overground could provide a useful measure of relative sprint performance. That is, based on our findings, it is likely that the individuals who are faster overground will, in most cases, be faster on the NMT, particularly over distances >20 m. Thus, it may be possible to identify faster athletes using NMT ergometry. However, this may not always be the case, with factors such as body mass likely to influence NMT sprint performance irrespective of overground sprint ability. Indeed, Lakomy (17) originally reported that the individuals with larger body masses were at an advantage on the NMT because of the force required to overcome the resistance of the NMT belt being relatively higher (per kilogram body mass) for lighter individuals.

Practical Applications

Our data offer support for NMT ergometry as a reliable tool for measuring particular sprint performance variables, namely, time to 20 and 30 m, peak and mean running speeds, and step length and frequency. This information can be used by sport and exercise practitioners not only to identify which measurements of sprint performance are reliable enough to be considered worthwhile but also to detect what might be considered 'real' changes in performance. For example, for somebody who attained a 30-m sprint time of 6 seconds, when tested on another day, they could attain anywhere between 5.69 and 6.53 seconds according to the 95% LoA (as a worst-case scenario). Thus, in theory, changes in sprint performance would have to be outside of these limits to be considered to be solely because of factors other than reliability. A further finding of this study is that the NMT is likely to be able to detect changes of 5% in many of the sprint performance variables measured with a sample size of approximately 10. Such information is useful for the design of future studies concerned with the NMT.

In relation to overground sprinting, it would appear that, in absolute terms, individuals were consistently slower on the NMT by approximately 25–30%. In relative terms, however, superior performances overground over 30 m were reflected in superior NMT performances, and as such, faster sprinters overground are likely to be identifiable via NMT ergometry over this distance. We conclude that the NMT is a useful tool for researchers and sports science practitioners wishing to examine changes in sprint performance, in particular over longer distances associated with team-sport activity. However, exercise practitioners should be cognizant that sprint times on the NMT might not always be representative of speed overground during competition and, therefore, should not disregard overground running as being an appropriate method of assessing sprint ability, particularly because it does not require familiarization (9). Nonetheless, there is the potential for a future, larger-scale study to examine whether overground sprint performance can be predicted with an acceptable degree of accuracy from the NMT measurements. More broadly, there is scope to embark on a more comprehensive evaluation of the efficacy of NMT sprint performance in relation to overground running by using force platform and video analysis systems.

References

1. Atkinson, G and Nevill, AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med* 26: 217–238, 1998.
2. Atkinson, G, Nevill, AM, and Edwards, B. What is an acceptable amount of measurement error? The application of meaningful 'analytical goals' to the reliability of sports science measurements made on a ratio scale. *J Sports Sci* 17: 18, 1999.
3. Bangsbo, J and Mohr, M. Variations in running speeds and recovery time after a sprint during top class soccer matches. *Med Sci Sports Exerc* 37: S87, 2005.
4. Bland, JM and Altman, DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* i: 307–310, 1986.
5. Bloomfield, J, Polman, R, and O'Donoghue, P. The 'bloomfield movement classification": Motion analysis of individual players in dynamic movement. *Int J Perform Anal Sport* 4: 20–31, 2004.
6. Duthie, GM, Pyne, DB, Ross, AA, Livingstone, SG, and Hooper, SL. The reliability of ten-meter sprint time using different starting techniques. *J Strength Cond Res* 20: 246–251, 2006.
7. Ellis, L, Gastin, P, Lawrence, S, Savage, B, Buckeridge, A, Stapff, A, Tumilty, D, Quinn, A, Woolford, S, and Young, W. Protocols for the physiological assessment of team sport players. In: *Physiological Tests for Elite Athletes.* C.J. Gore, ed. Champaign, IL: Human Kinetics, 2000. pp. 128–145.
8. Gabbett, TJ. A comparison of physiological and anthropometric characteristics among playing positions in sub-elite rugby league players. *J Sports Sci* 24: 1273–1280, 2006.
9. Glaister, M, Howatson, G, Lockey, RA, Abraham, CS, Goodwin, JE, and McInnes, G. Familiarization and reliability of multiple sprint running performance indices. *J Strength Cond Res* 21: 857–859, 2007.
10. Harris, NK, Cronin, JB, Hopkins, WG, and Hansen, KT. Squat jump training at maximal power loads vs heavy loads: Effect on sprint ability. *J Strength Cond Res* 22: 1742–1749, 2008.
11. Harriss, DJ and Atkinson, G. Ethical standards in sport and exercise science research. *Int J Sports Med* 30: 701–702, 2009.
12. Highton, JM, Twist, C, and Eston, RG. The effects of exercise-induced muscle damage on agility and sprint running performance. *J Exerc Sci Fitness* 7: 24–30, 2009.
13. Hopker, JG, Coleman, DA, Wiles, JD, and Galbraith, A. Familiarisation and reliability of sprint test indices during laboratory and field assessment. *J Sports Sci Med* 8: 528–532, 2009.
14. Hughes, MG, Doherty, M, Tong, RJ, Reilly, T, and Cable, NT. Reliability of repeated sprint exercise in non-motorised treadmill ergometry. *Int J Sports Med* 27: 900–904, 2005.
15. Krustrup, P, Mohr, M, Steensberg, A, Bencke, J, Kjaer, M, and Bangsbo, J. Muscle and blood metabolites during a soccer game: Implications for sprint performance. *Med Sci Sports Exerc* 38: 1165–1174, 2006.
16. Lakomy, HKA. An ergometer for measuring the power generated during sprinting. *J Physiol* 33: 354, 1984.
17. Lakomy, HKA. The use of a non-motorised treadmill for analysing sprint performance. *Ergonomics* 30: 627–637, 1987.
18. Lim, JM and Chia, MYH. Reliability of power output derived from the nonmotorized treadmill test. *J Strength Cond Res* 21: 993–996, 2007.
19. Magalhaes, J, Rebelo, A, Oliveira, E, Silva, JR, Marques, F and Ascensao, A. Impact of Loughborough intermittent shuttle test versus soccer match on physiological, biochemical and neuromuscular parameters. *Eur J Appl Physiol* 108: 39–48, 2009.
20. Markovich, G, Jukic, I, Milanovic, D, and Metikos, D. Effects of sprint and plyometric training on muscle function and athletic performance. *J Strength Cond Res* 21: 543–549, 2007.

21. Meir, R, Colla, P, and Milligan, C.Impact of the 10-meter rule change on professional rugby league: Implications for training. *J Strength Cond Res* 15: 450–458, 2001.
22. Meir, R, Newton, R, Curtis, E, Fardell, M, and Butler, B. Physical fitness qualities of professional rugby league players: Determination of positional differences. *J Strength Cond Res* 15: 450–458, 2001.
23. Moir, G, Sanders, R, Button, C, and Glaister, M. The effect of periodized resistance training on accelerative sprint performance. *Sports Biomech* 6: 285–300, 2007.
24. Myer, G, Ford, KR, Brent, JL, Divine, JG, and Hewett, TE. Predictors of sprint start speed: The effects of resistive ground-based vs. inclined treadmill training. *J Strength Cond Res* 21: 831–836, 2007.
25. Sirotic, AC and Coutts, AJ. The reliability of physiological and performance measures during simulated team-sport running on a non-motorised treadmill. *J Sci Med Sport* 11: 500–509, 2008.
26. Spencer, M, Bishop, D, Dawson, B, and Goodman, C. Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Med* 35: 1025–1044, 2005.
27. Spinks, CD, Murphy, AJ, Spinks, WL, and Lockie, RG. The effects of resisted sprint training on acceleration performance and kinematics in soccer, rugby union, and Australian football players. *J Strength Cond Res* 21: 77–85, 2007.
28. Tong, RJ, Bell, W, Ball, G, and Winter, EM. Reliability of power output measurements during repeated treadmill sprinting in rugby players. *J Sports Sci* 19: 289–297, 2001.
29. Zafeiridis, A, Saraslanidis, P, Manou, V, Ioakimidis, P, Dipla, K, and Kellis, S. The effects of resisted sled-pulling sprint training on acceleration and maximum speed performance. *J Sports Med Phys Fitness* 45: 284–290, 2005.