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Adam M. Gonzalez
University of Central Florida

Adam J. Wells
University of Central Florida

Jay R. Hoffman
University of Central Florida

Jeffrey R. Stout
University of Central Florida

Maren S. Fragala
University of Central Florida

See next page for additional authors

Authors

Adam M. Gonzalez, Adam J. Wells, Jay R. Hoffman, Jeffrey R. Stout, Maren S. Fragala, Gerald T. Mangine, William P. McCormack, Jeremy R. Townsend, Adam R. Jajtner, Nadia S. Emerson, and Edward H. Robinson IV

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Research article

Reliability of the Woodway Curve^{TM} Non-Motorized Treadmill for Assessing Anaerobic Performance

Adam M. Gonzalez ✉, Adam J. Wells, Jay R. Hoffman, Jeffrey R. Stout, Maren S. Fragala, Gerald T. Mangine, William P. McCormack, Jeremy R. Townsend, Adam R. Jajtner, Nadia S. Emerson and Edward H. Robinson IV
Institute of Exercise Physiology & Wellness, University of Central Florida, Orlando, FL, USA

Abstract

A curved treadmill offers a practical method of assessing anaerobic power by enabling unrestricted running motion and greater sport specificity. The purpose of this research was to determine reliability of a curved treadmill (cTM) sprint test and to compare performance measures to the traditional Wingate anaerobic power test (WAnT) performed on a cycle ergometer. Thirty-two recreationally active men and women (22.4 ± 2.8 yrs; 1.73 ± 0.08 m; 74.2 ± 13.2 kg) performed four familiarization trials on cTM, followed by two randomly assigned experimental trials consisting of one 30-second maximum effort on either cTM or WAnT. Each trial was separated by at least 48 hours. Repeated measures analysis of variance (ANOVA), interclass correlations (ICC), standard error of measurement (SEM), and minimal differences (MD) were used to determine reliability of familiarization trials on cTM, and Pearson product moment correlations were calculated to compare cTM and WAnT. ANOVA results showed significant differences ($p < 0.05$) during the four familiarization trials. Post hoc analysis showed significant differences ($p < 0.05$) between the first two trials. Familiarization trials 3 and 4 showed a high reliability for each performance variable (distance: $ICC_{2,1} = 0.969$, %SEM = 2.645, $p = 0.157$; mean velocity: $ICC_{2,1} = 0.969$, %SEM = 2.622, $p = 0.173$; peak velocity: $ICC_{2,1} = 0.966$, %SEM = 3.142, $p = 0.033$; mean power: $ICC_{2,1} = 0.940$, %SEM = 4.140, $p = 0.093$; and peak power: $ICC_{2,1} = 0.887$, %SEM = 11.244, $p = 0.669$). Participants elicited an average peak power of 1050.4±338.5 Watts on cTM and 1031.4±349.8 Watts on WAnT. Pearson product moment coefficients indicated high correlations between peak power, mean power, and peak velocity ($r = 0.75$, $p < 0.001$; $r = 0.84$, $p < 0.001$; and $r = 0.76$, $p < 0.001$, respectively) derived from cTM and WAnT. In conclusion, results suggest that after two familiarization trials, cTM is a reliable sprint test for recreationally active men and women. In addition, there are strong relationships between cTM and WAnT in assessing anaerobic performance.

Key words: Anaerobic capacity, power, Wingate anaerobic power test, sprint speed.

Introduction

Assessment of anaerobic power performance is an integral part of the monitoring and evaluation of strength and power athletes. Several laboratory and field assessments have been suggested as valid and reliable measures of anaerobic power performance (Hoffman, 2006). Laboratory measures have the advantage over field assessments by providing greater sensitivity and reliability in the evaluation of athletes. To date, the gold standard for anaerobic power assessment in the laboratory remains the Wingate anaerobic power test (WAnT) (Bar-Or, 1987, 1996; Bar-Or et al., 1977). Considering the test is performed on a cycle ergometer, the specificity for most competitive strength and power athletes is questionable. Several investigations have used jump tests to provide a greater specificity of power measurement, especially for basketball or volleyball athletes (Hertogh et al., 2002; Hoffman et al., 2000; Ostojic et al., 2010; Sayers et al., 1999). Although these assessments are able to assess peak or mean power performance in single or repetitive jumps, they are unable to provide any feedback regarding fatigue rate or anaerobic conditioning levels. The development of non-motorized treadmills has created the ability for athletes to generate maximal sprint speeds in a laboratory setting. Many of these treadmills are fitted with force transducers into the running platform that can assess force, velocity, and power performance. As such, these new treadmills may provide a more sport specific assessment of anaerobic power for field, court, and track athletes.

There have been several investigations examining the reliability and efficacy of flat non-motorized treadmills and their ability to assess power and anaerobic capacity (Highton et al., 2012; Hopker et al., 2009; Hughes et al., 2005; Lakomy, 1987; Lim and Chia,, 2007; Ross et al., 2009; Sirotic, et al., 2008; Tong et al., 2001). Previous research has shown high reliability similar to that seen with the WAnT (Lim and Chia, 2007); however the design of many non-motorized treadmills impedes natural running stride dynamics due to the use of bulky harnesses and instrumentation. In addition, some treadmills require subjects to overcome a resistance to start the sprint that demands a different running strategy than seen in a track-based sprint (Ross et al., 2009). Although training on a flat non-motorized treadmill has been shown to enhance power performance and improve sprint time (Ross et al., 2009), these benefits may only be realized during the initial acceleration phase (Hrysomallis et al., 2012).

Recently, a new treadmill (Woodway Curve 3.0^{TM}, Woodway, Inc., Waukesha, WI) was designed that allows unrestricted sprinting. The treadmill is designed with a curved platform to permit the runner to reach full velocity using running techniques that are similar to running on a track or field. Before tests of anaerobic power can be meaningful to sports training and assessment, reliability testing is necessary. Thus, the purpose of this study was to examine the reliability of this newly designed non-

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motorized treadmill on anaerobic power performance, and compare to values generated from the WAnT.

Methods

Participants

Twenty-four men and eight women (n=32; 22.4 ± 2.8 yrs; 1.73 ± 0.08 m; 74.2 ± 13.2 kg) volunteered to participate in the study. The research protocol was approved by the University's Institutional Review Board. Following an explanation of all procedures, risks, and benefits associated with the experimental protocol, each participant gave his or her written informed consent to participate in this study. All participants were recreationally active and were familiar with sprinting and cycling activities. None of the participants had any physiological or orthopedic limitations that could have affected performance as determined by completion of a health history questionnaire before participation. Participants were instructed to refrain from eating or drinking one hour prior to each trial.

Experimental design

Participants reported to the Human Performance Laboratory on six separate occasions. During the first four visits, participants performed familiarization sessions which provided detailed verbal instructions on the testing protocol and allowed acclimation to the device with lower intensity jogging. During each familiarization session, each participant completed one 30-s sprint test on the Woodway Curve 3.0™ non-motorized treadmill (cTM) (see Figure 1). There was at least 48 hours between each session. Following the four familiarization visits, the participants reported to the lab on two additional occasions and were randomly assigned to perform either a 30-s sprint on the cTM or a 30-s WAnT.

Figure 1. Woodway Curve 3.0™ Non-Motorized Treadmill (cTM)

Maximal treadmill sprint testing

Each familiarization trial and the 30-s treadmill sprint test were performed with identical protocols and were separated by at least 48 hours. Prior to the sprint, participants performed a 10-min warm-up consisting of 5-min on a cycle ergometer, followed by a 5-min walk on the cTM interspersed with two maximal sprints lasting 5-s. Following a 2-min rest, participants began one 30-s maximum effort sprint on the cTM. Prior to the onset of the sprint, participants walked at a pace of approximately 1.8 $m \cdot s^{-1}$ and were not allowed to accelerate until the start of the test. The study investigator provided a "Ready", "Set" and "Go" command. At "Go", participants began a maximal effort sprint for 30-s. Participants were verbally encouraged throughout the sprint. Data (distance, peak power, mean power, peak velocity, and mean velocity) were recorded from transducers built into the treadmill platform attached to the manufacturer's computer software (Pacer Performance System XPV7 2.1.07).

Wingate anaerobic power test (WAnT)

All participants performed one 30-s WAnT (Lode Excalibur™, Groningen, Netherlands). Prior to testing, participants completed a standardized warm-up consisting of 5-min pedaling at 60 rpm interspersed with two maximal sprints lasting 5-s. Prior to the onset of the test, participants pedaled at 60 rpm for 1-min and were not allowed to accelerate until the start of the test. The study investigator provided a "Ready", "Set" and "Go" command. At "Go", participants pedaled for 30-s at maximal speed against a constant force relative to individual body mass (0.7 $Nm \cdot kg^{-1}$) (Bar-Or, 1987). Peak power, mean power, and peak velocity were determined. Peak power was defined as the highest mechanical power output elicited during the test and mean power was defined as the average mechanical power during the 30-s test. The test-retest reliability of the WAnT has consistently exceeded $r > 0.90$ (Bar-Or, 1987).

Statistical analyses

Mauchly's test of sphericity was used to assess homogeneity of variance, and a Huynh-Feldt adjustment was used if assumptions of homogeneity were violated. A repeated measures analysis of variance (ANOVA) was used to detect differences in the variables calculated during each of the four trials (distance, mean velocity, peak velocity, mean power, peak power, relative mean power, and relative peak power). When appropriate, a tukey post hoc comparison was used. As recommended by Weir (2005) for describing the generalized reliability of the cTM procedure, intraclass correlation coefficients ($ICC_{2,1}$), standard error of measurement (SEM), standard error of measurement as a percent of the grand mean (%SEM), minimal difference (MD), and minimal difference as a percent of the grand mean (%MD) were calculated. In addition, Pearson product moment correlations were calculated between cTM and WAnT measures. For all statistical tests, a probability level of $p < 0.05$ was established to denote statistical significance. All data is presented as mean ± standard deviation.

Results

Performance data from the familiarization trials on cTM are presented in Table 1. The repeated measures ANOVA showed a significant ($p < 0.05$) systematic error during the four familiarization trials. Post hoc analysis of the 1st and 2nd cTM familiarization trials showed significant differences between trials for distance ($p = 0.005$), mean velocity ($p = 0.003$), peak velocity ($p = 0.012$), and mean

Table 1. Performance data from 30-s maximum sprint familiarization trials on cTM (±SD).

	Trial 1	Trial 2	Trial 3	Trial 4
Distance (m)	155.44 (23.66)	160.98 (23.97) *	165.13 (25.29) *	166.66 (23.23)
Mean Velocity ($m \cdot s^{-1}$)	5.16 (.82)	5.36 (.80) *	5.50 (.85) *	5.55 (.78)
Peak Velocity ($m \cdot s^{-1}$)	5.96 (.96)	6.19 (1.01) *	6.28 (1.03)	6.38 (.98 *
Mean Power (W)	260.53 (44.57)	282.41 (73.14) *	280.81 (45.89)	285.53 (45.61)
Peak Power (W)	981.09 (350.97)	992.78 (296.43)	1019.50 (332.58)	1031.88 (343.06)
Relative Mean Power (W/kg)	3.55 (.51)	3.86 (1.01)	3.84 (.60)	3.90 (.58)
Relative Peak Power (W/kg)	13.11 (3.22)	13.24 (2.57)	13.61 (3.10)	13.80 (3.16)

* Significant difference ($p < 0.05$) from previous trial.

power ($p = 0.049$). Analysis of the 2nd and 3rd cTM familiarization trials showed significant differences between trials for distance ($p = 0.001$) and mean velocity ($p < 0.000$). Analysis of the 3rd and 4th familiarization trials showed a significant difference between trials for only peak velocity ($p = 0.033$) (Table 1).

Reliability data for familiarization trials 3 and 4 are presented in Table 2. The 3rd and 4th familiarization trials showed strong intraclass correlations ($ICC_{2,1}$) ranging from 0.791-0.969 for all performance measures.

Performance data from the cTM and WAnT experimental sessions are presented in Table 3. Significant correlations between performance on the cTM and WAnT were observed for peak power ($r^2 = 0.56$, $p < 0.001$), relative peak power ($r^2 = 0.24$, $p = 0.005$), mean power ($r^2 = 0.71$, $p < 0.001$), and peak velocity ($r^2 = 0.58$, $p < 0.001$). Relative mean power between the cTM and WAnT was not significantly correlated ($r = 0.01$, $p = 0.508$).

Discussion

This study is the first to show that the cTM is a reliable sprint test for recreationally active men and women (Table 2). In addition, strong relationships among performance variables (Table 3) were demonstrated between cTM and WAnT. The findings of moderate to high shared variance for peak power ($r^2 = 0.56$), mean power ($r^2 = 0.71$), and peak velocity ($r^2 = 0.58$) between the methods provides support for the use of the cTM for assessing anaerobic performance capability in recreationally trained men and women.

Our data indicate that two familiarization trials, separated by at least 48 hours, are required prior to experimental testing to eliminate systematic error which is likely attributed to a learning effect. It has been suggested that assessing sprint performance on non-motorized treadmills require a familiarization period before reliable results are produced (Lakomy, 1987). Similarly, Hopker et al. (2009) demonstrated the need for familiarization due to the potential learning effects on a non-motorized treadmill. Using a similar group of men and women as recruited for this present study, Hopker et al. (2009) had participants perform four sprints on a flat non-motorized treadmill on separate days. Significant ($p < 0.05$) increases in mean and peak power were observed for the first 2 trials; however no further differences were seen in subsequent trials. Consequently, previous research utilizing flat non-motorized treadmills have employed a familiarization period prior to testing (Highton et al., 2012; Hughes et al., 2006; Sirotic et al., 2007; Tong et al., 2001). These studies support our findings and are consistent with the recommendation that two familiarization sessions should be performed on the cTM, separated by at least 48 hours, prior to experimental testing to improve reliability.

A 30-s maximum effort sprint test on the cTM is a reliable assessment of anaerobic power for recreationally active men and women showing strong ICC's ranging from 0.791-0.969 for performance measures. Previous research has investigated the reliability of flat non-motorized treadmills and yielded similar results. Hopker et al. (2009) reported ICC's ranging from 0.83-0.93 for mean power and 0.54-0.83 for average peak power (Hopker et al., 2009). Lim and Chia (2007) also reported significant intersession correlations (r's = 0.96 and 0.99) for mean and peak power, respectively, on a flat non-motorized treadmill. Others have reported coefficient of variations (CV) of 8.2 and 9.3 for mean and peak power, respectively (Tong et al., 2001). In agreement, the cTM used in the current study yielded ICC's of 0.94 and 0.89 and SEM% values of 4.14 and 11.24 for mean and peak power, respectively. Other investigations of flat non-motorized treadmills have also demonstrated strong reliability (Highton et al., 2012; Hughes et al., 2005; Sirotic et al., 2008). Despite strong reliability of flat non-motorized treadmills, altered running techniques during their use have raised concern (Ross et al., 2009). An apparent benefit of this present cTM is in its curved design

Table 2. Reliability data of familiarization trials 3 and 4 for 30-s maximum sprint on cTM.

	P-Value	$ICC_{2,1}$	SEM	%SEM	MD	%MD
Distance	.157	.969	4.387 m	2.645	11.674 m	7.037
Mean Velocity	.173	.969	.145 $m \cdot s^{-1}$	2.622	.388 $m \cdot s^{-1}$	7.016
Peak Velocity	.033 *	.966	.199 $m \cdot s^{-1}$	3.142	.489 $m \cdot s^{-1}$	7.725
Mean Power	.093	.940	11.723 W	4.140	30.214 W	10.670
Peak Power	.669	.887	115.326 W	11.244	317.972 W	31.001
Relative Mean Power	.133	.926	.167 $W \cdot kg^{-1}$	4.315	.435 W/kg	11.240
Relative Peak Power	.603	.791	1.500 $W \cdot kg^{-1}$	10.949	4.000 W/kg	29.197

* Significant difference ($p < 0.05$) between 3rd and 4th familiarization trial. $ICC_{2,1}$ = Intraclass Correlation Coefficient; SEM = Standard Error of Measurement; SEM (%) = Standard Error of Measurement as a Percent of the Grand Mean; MD = Minimal Difference; MD (%) = Minimal Difference as a Percent of the Grand Mean

Table 3. Performance data for 30-s maximum effort on cTM and WAnT (±SD).

	cTM	WAnT	r^2	p
Peak Power (W)	1050.4 (338.5)	1031.4 (349.8)	.56 *	.000
Mean Power (W)	293.0 (46.1)	625.7 (166.6)	.71 *	.000
Relative Peak Power ($W·kg^{-1}$)	14.1 (3.2)	13.7 (3.1)	.24 *	.005
Relative Mean Power ($W·kg^{-1}$)	4.1 (1.0)	8.3 (1.1)	.01	.508
Peak Velocity	6.5 (1.0) $m·s^{-1}$	133.5 (17.9) RPM	.58 *	.000

* Significant ($p < 0.05$) correlation between cTM and WAnT

that allows for unrestricted, maximum effort sprint assessment. It is also important to note that throughout the study, no participants fell or sustained any injury during familiarization or experimental testing sessions on cTM. Additionally, our results showed that a minimal difference of 31% in peak power needs to be exceeded for an improvement to be considered real (Weir, 2005).

WAnT has been considered the gold standard for assessing anaerobic power in a laboratory setting, and has shown to be reliable with test-retest coefficients between 0.89-0.97 (Bar-Or, 1987; 1996; Bar-Or et al., 1977). The newly designed cTM and WAnT demonstrated strong relationships for peak power, mean power, peak velocity, and relative peak power, however relative mean power did not show a significant relationship (Table 3). Further analysis of performance data indicate that participants elicited a greater peak power output on the cTM, whereas mean power output was greater on the WAnT. This is consistent with previous research illustrating greater peak power outputs on a non-motorized treadmill compared to a cycle ergometer as a result of the larger muscle mass involved in high velocity running (Falk et al., 1996). The cTM requires whole body muscle mass involvement during sprint performance accounting for the greater peak power, whereas the WAnT primarily activates lower body musculature during cycling allowing a greater mean power output over 30-s. The biomechanical differences between sprinting and cycling assessments account for the different performance values, but the high correlations show that the two assessments are related and reflect the maximal effort employed by participants during both assessments.

Conclusion

The cTM provides a practical method of assessing anaerobic power in a laboratory setting by enabling unrestricted running motion and greater specificity to sports that require high velocity running. The WAnT has been considered the standard for over a decade in physiology labs around the world (Bar-Or, 1987; 1996; Bar-Or et al., 1977), yet lacks specificity for most competitive strength and power sports which require running. Our results suggest that the cTM is a reliable assessment of anaerobic performance measures in recreationally active men and women. Future studies should investigate the validity of cTM to predict anaerobic performance in sports that require high velocity running.

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Key points

- The Woodway Curve 3.0™ is a non-motorized treadmill utilizing a curved platform which allows individuals to simulate an unrestricted sprint test in a laboratory setting, offering a practical and sport specific method of assessing anaerobic power.
- The curved treadmill provides a reliable sprint test for recreationally active men and women.
- There are strong relationships between the curved treadmill and cycle ergometer in assessing anaerobic performance.

AUTHORS BIOGRAPHY

Adam M. GONZALEZ
Employment
The University of Central Florida
Degrees
BSc, MEd
Research interests
Sports Science
E-mail: adam.gonzalez@ucf.edu

Adam J. WELLS
Employment
The University of Central Florida
Degrees
BSc, MS
Research interests
Sports Science
E-mail: adam.wells@ucf.edu

Jay R. HOFFMAN
Employment
The University of Central Florida
Degree
PhD
Research interests
Sports Science
E-mail: jay.hoffman@ucf.edu

Jeffrey R. STOUT
Employment
The University of Central Florida
Degree
PhD
Research interests
Sports Science
E-mail: Jeffrey.stout@ucf.edu

Maren S. Fragala
Employment
The University of Central Florida
Degree
PhD
Research interests
Sports Science
E-mail: maren.fragala@ucf.edu

Gerald T. MANGINE
Employment
The University of Central Florida
Degrees
BSc, MEd
Research interests
Sports Science
E-mail: Gerald.mangine@ucf.edu

William P. McCORMACK
Employment
The University of Central Florida
Degrees
BSc, MA
Research interests
Sports Science
E-mail: William.mccormack@ucf.edu

Jeremy R. TOWNSEND
Employment
The University of Central Florida
Degrees
BSc, MS
Research interests
Sports Science
E-mail: Jeremy.townsend@ucf.edu

Adam R. JAJTNER
Employment
The University of Central Florida
Degrees
BSc, MS
Research interests
Sports Science
E-mail: adam.jajtner@knights.ucf.edu

Nadia S. EMERSON
Employment
The University of Central Florida
Degree
BSc
Research interests
Sports Science
E-mail: nadia.emerson@ucf.edu

Edward H. ROBINSON IV
Employment
The University of Central Florida
Degrees
BSc, MA, MS
Research interests
Sports Science
E-mail: ned.robinson@ucf.edu

✉ **Adam M. Gonzalez**
Institute of Exercise Physiology & Wellness, University of Central Florida, Orlando, FL 32816, USA