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COMPARISON OF INTENSITY MARKERS AND CARDIORESPIRATORY RESPONSES IN MEASURING MAXIMUM OXYGEN CONSUMPTION BETWEEN A NON-MOTORISED AND MOTORISED TREADMILL PROTOCOL

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ABSTRACT

The objective was to compare cardiorespiratory parameters between two graded exercise protocols to determine which one is most appropriate for training prescription for male university level distance runners. The graded exercise tests, namely the Adapted Incremental Speed Protocol (AISP), and the Adapted Non-Motorised Incremental Speed Protocol (ANMIP) was used to compare several cardiorespiratory responses, as well as two intensity markers: the ventilatory threshold (VT) and the respiratory compensation point (RCP). The maximal oxygen consumption ($\dot{V}O_{2max}$) value of the ANMIP significantly ($p<0.05$) exceeded that of the AISP within a significantly ($p<0.05$) shorter time frame (8:19±0:52 vs. 11:25±1:11min). The percentage of $\dot{V}O_{2max}$ where VT and RCP were attained, was significantly higher ($p<0.05$) on the ANMIP (84.11±4.25 vs. 97.16±2.35%) compared to the AISP (75.74±7.84 vs. 93.3±3.86%). Consequently, the ANMIP is perceived substantially more difficult, both physiologically and psychologically. It can therefore be considered an ideal training tool to intensify exercise load with more time efficient training sessions for a distance running population. However, the obtained $\dot{V}O_{2max}$ results during the ANMIP could overestimate exercise prescriptions and should therefore not be used for these purposes.

Keywords: Exercise test; Exercise tolerance; Oxygen consumption; Physical exertion; Running performance.

INTRODUCTION

Maximum oxygen consumption ($\dot{V}O_{2max}$) is considered one of the fundamental building blocks for distance running performance (Basset & Howley, 2000). However, for a $\dot{V}O_{2max}$ value to be considered objective and sport-specific, the running modality needs to simulate over-ground running (OGR) closely, as this is the environment in which the distance runner trains and competes (Davies *et al.*, 1984). Motorised treadmills (MT) have been extensively used in laboratories as a valid tool for measuring endurance running performance despite the lack of any direct comparison to over-ground endurance performance (Stevens, *et al.*, 2015b). On the other hand, a newly designed Non-Motorised Treadmill (NMT), the Curve, has been presented as a valid tool for assessing endurance running performance (Stevens *et al.*, 2015b).

Motorised treadmills are controlled by a computer, through which speed and gradient are dictated and then propelled by a motor (Franks *et al.*, 2012). An athlete attempts to adapt to the set running speed of the MT by manipulating stride rate and length (Franks *et al.*, 2012).

Therefore, any changes in running pace are made consciously, with the MT belt enabling a runner to maintain a more consistent running speed (Stevens *et al.*, 2015a). The MT has consequently become popular among endurance runners (Wank *et al.*, 1998). In contrast with the MT, the Curve NMT's new 'bean' shaped geometric design (Stevens *et al.*, 2015b) dictates an increasing gradient of 6-10° (Smoliga *et al.*, 2015). When running on the Curve NMT, the athlete is in control of the speed of the belt by driving through each subsequent step (Snyder *et al.*, 2011). An additional benefit of the Curve NMT is that it allows unrestricted running motion (Grassi *et al.*, 2015) and therefore greater sport specificity (Gonzalez *et al.*, 2013). The self-pacing nature of the Curve NMT agrees with OGR and is, therefore, regarded as more consistent with OGR than MT running (Stevens *et al.*, 2015b). Based on these mechanical differences, cardiorespiratory responses measured on the MT and Curve NMT were expected to differ.

Cardiorespiratory responses obtained from MT and OGR during a continuous graded exercise test (GXT) protocol were found to be similar, even though OGR allowed athletes to attain higher running speeds (Meyer *et al.*, 2003). No significant differences in MT running and OGR $\dot{V}O_{2max}$ values (63.5 *vs.* 63.3 ml/kg/min) were measured, although statistically significant differences ($p<0.001$) were measured for time to exhaustion (T_{lim}) (11:31 *vs.* 12:07), as well as maximum heart rate (HR_{max}) (188 *vs.* 189 bpm). Furthermore, significant differences ($p<0.001$) were evident in measures of minute ventilation ($\dot{V}_E$) (Meyer *et al.*, 2003), and as a result energy cost consequently differed, with the MT energy cost exceeding that of OGR.

When comparing the NMT and OGR during a 5km-time-trial, both the Curve NMT and OGR attained similar cardiorespiratory responses with respect to oxygen utilised ($\dot{V}O_2$) (51.1 *vs.* 49.2 ml/kg/min), heart rate (HR) (178 *vs.* 178 bpm), as well as $\dot{V}_E$ (122.0 *vs.* 122.4 L/min). However, rating of perceived exertion (RPE) (6.5 *vs.* 6.1) and blood lactate values (9.4 *vs.* 7.8 mmol/L) were significantly ($p<0.05$) higher on the Curve NMT compared to OGR. These responses were attributed to the natural gradient of the Curve NMT that was perceived to be more difficult than OGR (Stevens *et al.*, 2015b). These results led Stevens *et al.* (2015b) to regard the Curve NMT as a valid tool for assessing endurance running performance; however, values attained by a 5km-time-trial cannot be compared directly to $\dot{V}O_{2max}$ results.

Early research from Davies *et al.* (1984) compared MT running to NMT running and found similar results for $\dot{V}O_{2max}$ values (59.6 *vs.* 61.4 ml/kg/min). The $\dot{V}O_{2max}$ value of the NMT exceeded that of all MT tests conducted, but was not statistically significantly higher. Furthermore, the NMT attained $\dot{V}O_{2max}$ within a shorter running time than all other MT tests (6.0 *vs.* 8.1 min). However, the NMT used in this research study was flat and results obtained by this NMT are therefore not comparable to the Curve NMT. More recently, Snyder *et al.* (2011) compared submaximal cardiorespiratory responses measured on a MT to a Curve NMT by using a discontinuous test protocol. All responses measured, $\dot{V}O_2$ (49.9 *vs.* 60.2 ml/kg/min), HR (170 *vs.* 190 bpm), RPE (4.1 *vs.* 8.2), and blood lactate (4.5 *vs.* 11.1 mmol/L), were significantly higher ($p<0.05$) on the Curve NMT than on the MT. Nevertheless, the use of discontinuous test protocols has been found to be time-consuming and the use of continuous GXT protocols was preferred (Meyer *et al.*, 2003).

From these findings it is clear that a single running modality has not yet been prescribed as the gold standard for $\dot{V}O_{2max}$ testing, specifically with the use of a continuous GXT protocol. The aim of this research study was to compare cardiorespiratory parameters between two graded exercise protocols to determine which one is most appropriate for training prescription.

METHODOLOGY

Experimental design

The experimental approach was to compare cardiorespiratory parameters between two graded exercise protocols to determine which one is most appropriate for training prescription. The Oxycon Pro static ergo spirometry system (Jaeger Oxycon Pro, Viasys, 22745, Savi Ranch Parkway, Yorba Linda, CA, USA) was used to measure all cardiorespiratory variables. Two treadmill test protocols (see *Procedure*) were performed on two different treadmill modalities, namely the Woodway Pro XL MT (Woodway, W229 N591, Foster Ct, Waukesha, WI) and the Woodway Curve 1 NMT (Woodway, W229 N591, Foster Ct, Waukesha, WI).

Subjects

Twelve male distance runners (age: 21.8 ± 3.0 yrs.; stature: 178.2 ± 6.5 cm; body mass: 66.7 ± 4.7 kg), who were part of the senior university athletics squad, participated in this research study. All participants competed and trained during the 2016 season and had to participate in both university cross-country and track running. All tests in this research study were performed during the track season. Participants consented in writing to participate after being fully informed of the nature of this research study, including possible benefits and risks. The Health Research Ethics Committee (HREC) from the university, where the study was conducted (NWU-00201-15-A1), approved the testing procedure. Participating distance runners had to be injury-free during the testing period and had to complete all tests involved in the research study.

Measurements

The following GXT protocols were conducted with specific adaptations made to existing protocols for comparability purposes.

Adapted Incremental Speed Protocol (AISP)

The AISP performed on the MT was adapted from the speed GXT protocol of Davies *et al.* (1984). The AISP started at a speed of 14km/h with increases of 1km/h each minute until exhaustion. The starting speed of the AISP was adapted from 14km/h to 10km/h to allow comparability to the NMT GXT protocol following.

Adapted Non-motorised Incremental Speed Protocol (ANMIP)

The ANMIP performed on the Curve NMT was adapted from the NMT GXT protocol of Davies *et al.* (1984). The ANMIP started at a speed of 10km/h with a 2km/h increase every 3 minutes until exhaustion. The time intervals of the ANMIP were adapted from 3 minutes to 2 minutes to allow comparability each 2 minutes with the AISP. Because of pacing difficulty on the NMT, 2-minute rather than 1-minute time intervals were selected.

Procedures

Two familiarisation sessions were completed two weeks prior to the tests on both the MT and NMT. All sessions started at 10km/h and increased by 1km/h each 1-minute time interval for the MT and 2km/h each 2-minute time interval on the NMT for approximately 4 minutes, where after a comfortable pace was reached and running continued for 10 minutes. These familiarisation sessions were considered adequate (Borg, 1982).

Participants were required to participate in two GXT protocols, of which the earlier AISP mentioned was performed on the Woodway Pro XL MT and the ANMIP on the Woodway

Curve 1 NMT. Both test protocols were performed at the same time of day within a time frame of five days. Participants were healthy (Physical Activity Readiness Questionnaire) and well-hydrated (hydration status and recovery questionnaire) at the time of participation. The laboratory's temperature was controlled to stay within 19° to 21°C. Participants were requested to follow a normal diet throughout the research period and abstain from food (2 hours), alcohol and coffee (12 hours), and vigorous training (48 hours) before the tests.

A profile was created for each participant by measuring his stature and body mass the day of the test on arrival at the laboratory. Each GXT protocol was preceded by a 10-minute warm-up consisting of treadmill running at 10km/h for 1km, followed by a set of dynamic stretches. After completing the warm-up, participants were fitted with a HR monitor belt (Polar Electro, Kempele, Finland: T34) for HR measurement and a face mask for breath analysis. Once the GXT protocol started, the cardiorespiratory responses HR_{max}, oxygen consumed ($\dot{V}O_2$), carbon dioxide produced ($\dot{V}CO_2$), $\dot{V}_E$, $\dot{V}O_{2max}$, oxygen utilised ($\dot{V}O_2$), $\dot{V}_E$, respiratory exchange ratio (RER), and T_{lim}, were recorded every 15 seconds during the tests by the Oxycon Pro static ergo spirometry system (Jaeger Oxycon Pro, Viasys, 22745, Savi Ranch Parkway, Yorba Linda, CA, USA). Each participant was motivated to continue the GXT protocol for as long as possible until exhaustion. Rating of perceived exertion was obtained from the participant in the last 10 seconds of each level according to the Borg Scale (CR-10 Scale) (Stevens *et al.*, 2015b). Participants communicated using a basic signaling system of thumbs up – continue, and thumbs down - stop at the end of the level. The GXT protocols were terminated on reaching complete exhaustion, after which HR recovery was taken at 1-, 3-, and 5-minutes rest.

Two experienced sport scientists determined the ventilatory threshold (VT) and respiratory compensation point (RCP) by using a plotted graph on which the increases and decreases in $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ values were presented. The VT was identified as the point where the $\dot{V}_E/\dot{V}O_2$ increased without a corresponding change in the $\dot{V}_E/\dot{V}CO_2$ or departure in the linearity of the $\dot{V}_E$ line. The RCP was identified as the point where both the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E / V\dot{C}O_2$ increased dramatically (Chicharro *et al.*, 2000). In cases where the two sport scientists did not agree, a third sport scientist was consulted. Time to exhaustion was measured from the starting speed of 10km/h to the point where the GXT protocol was terminated owing to exhaustion.

The criterion used to determine the achievement of a $\dot{V}O_{2max}$ was the attainment of at least two of the following criteria:

- An RER value of >1.10 (Haff & Dumke, 2012; Hamlin *et al.*, 2012);
- A plateau in $\dot{V}O_2$ (<150 ml/min) (Davis, 2006; Haff & Dumke, 2012; Hamlin *et al.*, 2012);
- An RPE (CR 10-Scale) of 10 (Borg & Kaijser, 2006), and the attainment of A HR_{max} at 90% of predicted HR_{max} (Hamlin *et al.*, 2012) as determined by using the formula of 208-(0.7 x age) (Tanaka *et al.*, 2001; Wilmore *et al.*, 2008).

If only one criterion was attained, it was graded a peak aerobic capacity ($\dot{V}O_{2peak}$) value and participants' results were excluded from this study.

Statistical analyses

The statistical data processing package SPSS Statistics (version 27.0.0.0) was used to process the data. All variables are presented as mean±standard deviation (SD). Percentage difference and 90% confidence intervals are reported for all comparisons between protocols. Due to the small sample size, a Wilcoxon rank test performed to determine any significant differences between AISP and ANMIP with the level of significance set at $p<0.05$ (Field, 2009). To determine the effect size, a rank-biserial correlation (r-value) was used with guideline values of 0.1 for small, 0.3 for medium, and 0.5 for large effect size (Pallant, 2007).

RESULTS

The cardiorespiratory responses are shown in Table 1.

***Table 1*. MEAN CARDIORESPIRATORY RESPONSES FROM MAXIMUM VALUES ATTAINED BY AISP AND ANMIP AND DIFFERENCES** (n=12)

Cardio-respiratory responses	**Protocol**	**Mean±SD**	**%Diff**	**90% CI: Lower**	**90% CI: Upper**	**p-value**	**r-value**
T_{lim} (min)	AISP	11:25±01:11	37.83	31.73	43.92	0.002*	0.63^L
	ANMIP	08:19±00:52					
HR_{max} (bpm)	AISP	192±9.04	0.38	-1.95	2.71	0.754	0.06
	ANMIP	192±10.3					
RER	AISP	1.16±0.05	-1.01	-3.08	1.06	0.398	0.17^S
	ANMIP	1.17±0.04					
$\dot{V}O_{2max}$ (ml/kg/min)	AISP	65.04±4.43	-2.5	-4.45	-0.56	0.034*	0.43^M
	ANMIP	66.73±3.99					
RPE	AISP	9.00±1.24	-2.73	-8.33	2.87	0.334	0.20^S
	ANMIP	10.00±0.65					
VT (ml/kg/min)	AISP	49.28±6.25	-12.08	-17.24	-6.91	0.005*	0.58^L
	ANMIP	56.09±3.96					
VT (min)	AISP	04:55±01:44	56.53	22.45	90.61	0.011*	0.52^L
	ANMIP	03:20±00:59					
RCP (ml/kg/min)	AISP	60.72±5.31	-6.39	-8.82	-3.95	0.003*	0.60^L
	ANMIP	64.78±3.29					
RCP (min)	AISP	08:45±01:46	37.26	24.47	50.06	0.003*	0.61^L
	ANMIP	06:25±01:00					
VT% of $\dot{V}O_{2max}$	AISP	75.74±7.84	-3.95	-14.61	-5.15	0.006*	0.56^L
	ANMIP	84.11±4.25					
RCP% of $\dot{V}O_{2max}$	AISP	93.30±3.86	-9.88	-6.07	-1.82	0.015*	0.50^L
	ANMIP	97.16±2.35					

AISP=Adapted Incremental Speed Protocol ANMIP=Adapted Non-motorised Incremental Speed Protocol
HR_{max}= Maximum heart rate HR=Heart rate RER= Respiratory exchange ratio
RPE=Rating of perceived exertion RCP= Respiratory compensation point;
T_{lim} =Time to exhaustion $\dot{V}O_{2max}$=Maximal oxygen consumption VT=Ventilatory threshold.
SD= Standard deviation *Statistical significance (p<0.05 L=Large effect M=Medium effect S=Small effect

The percentage difference between the cardiorespiratory responses obtained from the AISP and ANMIP resulted in eight out of eleven responses of the ANMIP exceeding that of the AISPs (RER, $\dot{V}O_{2max}$ (ml/kg/min), RPE, VT (ml/kg/min), RCP (ml/kg/min), VT% of $\dot{V}O_{2max}$, RCP% of $\dot{V}O_{2max}$). The results obtained from the Wilcoxon rank test found the ANMIP T_{lim} to be statistically significantly (p=0.002) lower than that of the AISP (08:19±00:52 *vs.* 11:25±01:11min.). The ANMIP's $\dot{V}O_{2max}$ were also statistically significantly (p=0.034) higher than the AISP's (66.73±3.99 *vs.* 65.04±4.43 ml/kg/min). Furthermore, all responses with regard to VT and RCP were found to be statistically significantly higher (p=0.003 to 0.034) with the ANMIP exceeding that of the AISP except for VT min (3.33±0.98 *vs.* 4.92±1.73 min) and RCP min (6.42±1.00 *vs.* 8.75±1.76 min).

Table 2 (landscape on next page) presents the differences between the measured cardiorespiratory responses for AISP and ANMIP for each speed interval. It should be noted that the AISP lasted longer than the ANMIP, consequently speed comparisons could only be made up until 18km/h. All measures of HR, $\dot{V}O_2$, $V\dot{C}O_2$, $\dot{V}_E$, $\dot{V}O_2$ utilised, RER, HR and RPE obtained large effect (r>0.5) for all speeds used (10, 12, 14, 16, and 18 km/h) between the two running modalities, with the ANMIP values significantly higher (p<0.05) than the AISP values.

DISCUSSION

The objective of this study was to compare cardiorespiratory parameters between two graded exercise protocols to determine which one is most appropriate for training prescription for male university-level distance runners. The main finding of this study was that although the Curve NMT's cardiorespiratory responses predominantly exceeded the MT responses within a shorter running time, it is not suitable for exercise prescriptions.

According to cardiorespiratory responses in Table 1, the $\dot{V}O_{2max}$ values of the ANMIP exceeded those of the AISP significantly (p=0.034; r=0.43). It is, however, noteworthy that the ANMIP values were attained within a statistically significantly (p=0.002) shorter time frame (8:19±0:52 *vs.* 11:25±1:11 min) compared to the AISP, also evident in the 90% CI measures with worthwhile effect in favour of the AISP. These findings are parallel to the results of Davies *et al.* (1984) who used a NMT and MT along with similar GXT protocols as used in this study. In the above-mentioned study, the NMT attained higher $\dot{V}O_{2max}$ values (61.4 *vs.* 59.0 ml/kg/min) within a shorter running time (6.0 *vs.* 8.1 min) compared to the MT, even though a NMT with a flat running surface was used (Davies *et al.*, 1984). These results indicate higher exercise intensity on the Curve NMT compared to the MT.

Results reported in Table 2 indicate that the ANMIP's cardiorespiratory responses exceed those of the AISP for each speed compared over the course of the two GXT protocols. All responses of the ANMIP, namely HR, $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$, $\dot{V}O_2$ utilised, RER and RPE, significantly (p<0.05; r>0.5) exceeded responses of the AISP. Therefore, it is clear that the physical demands set by the Curve NMT, owing to its mechanical differences, exceed those of the MT, as running on the Curve NMT has been described as similar to running uphill (Franks *et al.*, 2012; Smoliga *et al.*, 2015). Furthermore, the energy cost of running on the Curve NMT surpasses that of the MT owing to higher friction of the belt and higher muscle activation (Franks *et al.*, 2012). It seems that the Curve NMT is thought to be physically more challenging, and exhausting compared to the MT and consequently these modalities should rather not be compared in this manner.

An interesting finding of this study was that the percentage of $\dot{V}O_{2max}$, where VT and RCP were attained, was significantly higher (p=0.006 and p=0.015, respectively) on the ANMIP compared to the AISP (Table 1), with supporting 90% CI measures indicating a substantial effect in favour of the ANMIP.

Table 2. CARDIORESPIRATORY RESPONSE VALUES PER SPEED FOR AISP AND ANMIP

Speed	**Protocol**	**n**	**Cardiorespiratory Response**						
			$\dot{V}_E$ (L/min)	**RER**	**$\dot{V}O_2$ (ml/min)**	**$\dot{V}CO_2$ (ml/min)**	**$\dot{V}O_2$ (ml/kg/min)**	**HR (bpm)**	**RPE**
10 km/h	AISP	12	59.6	0.79	2398	1890	36	134.1	1.4
	ANMIP	12	96.9 ^{*L}	0.87 ^{*L}	3412 ^{*L}	2984 ^{*L}	51.1 ^{*L}	155.6 ^{*L}	2.3 ^{*L}
	%diff		-36.5	-8.93	-30	-36	-29.6	-14	-27
	(90% LCI;UCI)		(-41.2;-31.8)	(-12.87;-4.99)	(-32;-28)	(-39;-33)	(-31.4;-27.8)	(-17;-11)	(-46;-9)
12 km/h	AISP	12	74.7	0.86	2834	2431	42.4	147.2	2.1
	ANMIP	12	120.7 ^{*L}	0.95 ^{*L}	3868 ^{*L}	3701 ^{*L}	57.9 ^{*L}	168.8 ^{*L}	4.1 ^{*L}
	%diff		-37.5	-10.37	-27	-34	-26.8	-13	-47
	(90% LCI;UCI)		(-41.4;-33.7)	(-13.34;-7.39)	(-29;-24)	(-38;-31)	(-29.4;-24.2)	(-16;-10)	(-59;-35)
14 km/h	AISP	12	91	0.89	3302	2959	49.3	158.6	3.3
	ANMIP	12	145.2 ^{*L}	1.05 ^{*L}	4243 ^{*L}	4437 ^{*L}	63.6 ^{*L}	179.8 ^{*L}	6.9 ^{*L}
	%diff		-37.1	-14.36	-22	-34	-22.4	-12	-53
	(90% LCI;UCI)		(-40.6;-33.5)	(-17.29;-11.44)	(-25;-20)	(-36;-31)	(-24.8;-19.9)	(-14;-9)	(-62;-44)
16 km/h	AISP	12	111.3	0.95	3696	3530	55.1	170.4	5.1
	ANMIP	12	166.3 ^{*L}	1.12 ^{*L}	4433 ^{*L}	4948 ^{*L}	66.4 ^{*L}	186.3 ^{*L}	8.9 ^{*L}
	%diff		-33.1	-14.87	-17	-29	-16.9	-9	-43
	(90% LCI;UCI)		(-36.3;-29.9)	(-17.98;-11.77)	(-20;-13)	(33;-25)	(-19.7;-14.1)	(-11;-6)	(-53;-33)
18 km/h	AISP	12	144.7	1.04	4094	4272	61.1	181.4	7
	ANMIP	4	188.2 ^{*L}	1.15 ^{*L}	4568 ^{*L}	5249 ^{*L}	68.2 ^{*L}	198.9 ^{*L}	10.7 ^{*L}
	%diff		-23.8	-12.05	-9	-20	-8.9	-8	-40.0
	(90% LCI;UCI)		(-34.4;-13.1)	(-18.41;-5.68)	(-14;-5)	(-28;-12)	(-12.3;-5.4)	(-13;-2)	(-69;-11)

AISP=Adapted Incremental Speed Protocol; ANMIP=Adapted Non-motorised Incremental Speed Protocol; HR=Heart rate; RER==Respiratory exchange ratio; RPE=Rating of perceived exertion; $\dot{V}_E$=Minute ventilation; $\dot{V}O_2$=Oxygen consumed (ml/min); $\dot{V}CO_2$=Carbon dioxide produced (ml/min); $\dot{V}O_2$=Amount of oxygen utilised (ml/kg/min);
%diff: percentage difference; LCI=Lower confidence interval; UCI=Upper confidence interval; n=Number of participants; L=Large effect.

These findings are supported by other cardiorespiratory responses of both MT and NMT exceeding that of OGR (Meyer *et al.*, 2003; Stevens *et al.*, 2015b). Cardiorespiratory responses such as blood lactate, as well as RPE values on the NMT, exceed that of OGR (Stevens *et al.*, 2015b) and indicate the difficulty level and order of difficulty among these modalities. Therefore, one can derive that a similar effect is expected regarding the VT and RCP intensity markers, as this too is influenced by the presence of an anaerobic response. The reason for this finding is not clear, however, a possible explanation might be seen in the results from Table 2.

All measures of the ANMIP exceeded measures of the AISP, therefore one can derive that the exercise intensity on the Curve NMT is therefore considered to be higher than that of the MT, possibly caused by additional recruitment of type II muscle fibres (Xu & Rhodes, 2016). The recruitment of type II muscle fibres and increased ventilation are considered contributing factors to the manifestation of the 'slow component' of $\dot{V}O_2$ kinetics and can cause an increase in the oxygen cost of exercise. This component is characterised by a slow increase in $\dot{V}O_2$ during incremental exercises (Krustrup *et al.*, 2004; Grassi *et al.*, 2015; Xu & Rhodes, 2016). Furthermore, extremely intense exercises are so severe that exhaustion intervenes before the kinetics of $\dot{V}O_2$ allows the attainment of a higher $\dot{V}O_{2max}$ (Jones *et al.*, 2011). Intense exercise is also associated with the occurrence of hyperventilation due to the body's attempt to attain effective gas exchange in the lungs by increasing ventilatory work, causing a further increase in the 'slow component' (Xu & Rhodes, 2016). These findings are supported by the high percentages of VT and RCP (Table 1) expressed through $\dot{V}O_{2max}$ that might have occurred in response to hyperventilation.

With regard to exercise prescription, the values attained by the ANMIP are unsuitable. From past research, the VT and RCP for endurance trained sportsmen are expected to occur close to 65% and 90% respectively (Chicharro *et al.*, 2000). The exceptionally high intensity markers (VT: 84.1±4.3%; RCP: 97.2±2.4%) attained by the ANMIP are not recommended because of the intense effect these high percentage exercises will have on muscle recruitment and ventilatory work. Training at these extreme intensity markers is bound to have a destructive effect on performance. Nevertheless, training on the Curve NMT might be beneficial to intensify exercise with its added training load.

It is clear from all of the above findings that physically, the ANMIP is more strenuous than the AISP. From a psychological perspective, the perceived exertion measured by the RPE of the ANMIP predominantly exceeded that of the AISP ($r>0.05$) for every speed interval (Table 2) as well. These findings are similar to the findings of Smoliga *et al.* (2015) who compared the Curve NMT to a MT, where measured RPE responses were significantly higher ($p<0.05$) on the Curve NMT at a walking and running speed (Smoliga *et al.*, 2015). Therefore, the Curve NMT was rated to be perceived as substantially more strenuous than the MT (Smoliga *et al.*, 2015; Stevens *et al.*, 2015b).

Even though the speeds of the two GXT protocols (ANMIP and AISP) running modalities correspond, the physical demands required from the athlete for the same speed on the respective modalities are not equivalent (see Table 2). Furthermore, the measured HR (104.4 *vs.* 82.7 bpm; 151.6 *vs.* 120.6 bpm) and $\dot{V}O_2$ (1.39 *vs.* 0.8 L/min; 2.53 *vs.* 1.76 L/min) were found to be significantly higher on the Curve NMT (Smoliga *et al.*, 2015) compared to a MT at walking and running speeds. These findings are also in line with the results from this study.

LIMITATIONS

Some limitations can be noted. The study made use of a small group of athletes (due to availability) and was also limited to a specific time of season. $\dot{V}O_{2max}$ Test results obtained on the Curve NMT's VT and RCP values obtained are not recommended for exercise prescription. From the vast pool of GXT's used for determination of maximal oxygen consumption, only a handful of GXT's were considered appropriate to use for comparison and even then adaptations to the GXT's were required. The GXT selected on the Curve NMT used large interval sizes and can be considered a limitation due to the treadmill's pacing nature.

CONCLUSION

The results from this study suggest that the Curve NMT (ANMIP) is substantially more difficult than MT running (AISP), both physiologically and psychologically. Even though higher cardiorespiratory responses were attained using the Curve NMT (ANMIP), the intensity markers obtained, namely VT and RCP, were not applicable for exercise prescription. Nevertheless, the Curve NMT can be used to intensify exercise with its added training load.

PRACTICAL APPLICATION

The cardiorespiratory responses of a $\dot{V}O_{2max}$ test performed on a Curve NMT exceed those of a MT. Performing $\dot{V}O_{2max}$ tests on the Curve NMT is found to be time-efficient for a distance running population, however, the VT and RCP values obtained are not applicable for exercise prescription. The Curve NMT can be considered an ideal training tool to intensify exercise load.

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