Sprint interval training on the vertical treadmill improves aerobic and anaerobic running performance

Abstract

The vertical treadmill (VertiRun, UK) is an unresearched mode of exercise where users engage in a "running-like" action whilst body weight is supported by a recumbent bench and overhanging resistance cables are tethered to the user's ankles. The purpose of this study was to determine the effects of training on a VertiRun and any cross-training effect on running performance. Thirty active males (age 22 ± 4 years, stature 1.79 ± 0.08 m, mass 78.5 ± 12.6 kg) volunteered for this study. Participants' aerobic and anaerobic running performance were determined by incremental VO_{2max} treadmill test and a maximum anaerobic running test (MART), respectively. Participants were matched and then randomly assigned to either a VertiRun group, 20 m shuttle sprint group or control group. The intervention consisted of 4-6, 30 s all-out efforts with 4 minutes recovery between bouts, 3 days a week for 6 weeks. The pre and post intervention VO_{2max} and MART were analysed using a mixed repeated measures ANOVA. MART increased by 4.5% in the VertiRun group (P=0.006) and 4% in the sprint group (P<0.001). VO_{2max} increased by 6.2% in the VertiRun group (P=0.009) and 5.5% in the sprint group (P=0.020). The MART and VO_{2max} of the control group were unchanged (P=0.910 and P=0.915, respectively). These data suggest that the VertiRun could be an effective cross-training mode for running and could supplement training programmes. Also, as VertiRun is a low-impact exercise it might be useful in the physical preparation of athletes returning to sport following lower limb injury.

Keywords: VertiRun, Cross-training, Low impact exercise, Non-weight bearing, Aerobic training, Anaerobic training

INTRODUCTION

The specificity principle denotes that central and peripheral adaptations are specific to the training stimulus and exercise mode (Millet et al., 2009). In contrast with the specificity principle, training programmes usually incorporate elements of cross-training where the athlete engages with exercise modes that differ from the competition mode, with the intention of improving cardiovascular and musculoskeletal performance (Flynn et al., 1998; Foster et al., 1995). Cross-training for sports that involve large volumes of high speed running often includes partial or non-weight bearing exercise such as cycling, recumbent stepping, antigravity treadmill running and aquatic exercise to reduce the mechanical load on the musculoskeletal system and potentially prevent overuse injuries (Hreljac, 2004; Sobhani et al., 2013). The training stimulus from partial and non-weight bearing exercise differs from overground running due to innate differences in the exercise modes. Despite differences in the mode, cross-training can improve, or at least maintain running performance in untrained to moderately trained athletes (Hass et al., 2001; Joubert et al., 2011; Loy et al., 1994; Millet et al., 2002; Millet al., 2009; Mutton et al., 1993).

The vertical treadmill (VertiRun, UK) is a new, unresearched low-impact exercise mode that could be a useful cross-training mode for running because users engage in a "running-like" action with body weight supported (Jordan et al., 2017). The VertiRun consists of a vertically hung, non-motorised treadmill, an adjustable bench mechanism and overhanging resistance cables (Fig.1.). The body posture and position of the user, with respect to the treadmill belt, can be manipulated by adjusting the bench angle and fore and aft settings. The overhanging cables are tethered to the ankle and offer resistance to the musculature of the posterior chain (20 N on the uptake of tension, up to 70 N as the leg descends to the lowest point of the treadmill). Therefore, the magnitude of the resistance is dependent on the leg length, leg mass and the lower limb range of motion of the user.

Figure 1 about here

VertiRun exercise appears to be similar in nature to running with the benefit of a resistive component (Jordan et al., 2017) and could be an appropriate cross-training exercise for any athlete for which running is the mode of locomotion. Currently, the VertiRun lacks peer reviewed research as a cross-training exercise and practitioners lack the evidence to support the use of VertiRun in training programmes. Therefore, the purpose of this study was to determine the efficacy of VertiRun training on aerobic and anaerobic running performance.

MATERIALS AND METHODS

Participants

After institutional ethics approval, thirty male participants (age 22 ± 4 years, stature 1.79 ± 0.08 m, body mass 78.5 ± 12.6 kg) were informed of the benefits and risks of the investigation prior to providing written consent to participate in the study. All participants were healthy, physically active students and engaged in intermittent sprint-type sports (rugby, soccer, hockey) two to three times per week.

Procedure

One week prior to commencing with the study, all participants undertook familiarisation of the intervention tests and the VertiRun. VertiRun familiarisation sessions consisted of 2 x 30 minutes of sub-maximal exercise with very brief maximal efforts (3-5 reps, 20 s). Following familiarisation, aerobic and anaerobic running performance of the participants was assessed by an incremental VO_{2max} test and Maximal Anaerobic Running Test (MART), respectively. The VO_{2max} and MART tests were separated by 48 hours rest. Each testing session began with a self-selected 'light' warm up, rated 9 on Borg's Rating of Perceived Exertion scale (RPE) (Borg, 1998) on a conventional motorised treadmill with a 1º incline

(Saturn, HP Cosmos, Nussdorf-Traunstein, Germany) for 5 minutes, followed by 5 minutes of self-selected dynamic stretches.

Maximal Aerobic Running Capacity (VO_{2max})

The VO_{2max} was determined by breath-by-breath pulmonary gas analysis (CPX Ultima, MedGraphics Corporation, St. Paul, Minnesota, USA) during an incremental test on a conventional motorised treadmill with 1° incline throughout. The initial speed was 9 $km \cdot h^{-1}$ and increased by 1 $km \cdot h^{-1}$ every minute until volitional fatigue. Pulmonary gas analysis was recorded throughout the test, heart rate and RPE were recorded 15 s before the end of every minute and at volitional fatigue. Blood lactate concentration ([BLa]) was measured immediately after the VO_{2max} test via the finger prick method and analysed (YSI1500 Sport Lactate Analyser, YSI Inc., Yellow Springs, Ohio, USA). The VO_2 data was subject to 30 s averaging and was plotted against exercise intensity. The highest interval indicated VO_{2max} and was verified by a plateau in the VO_2-intensity relationship, a respiratory exchange ratio of at least 1.15 and an RPE of 18-20.

Maximal Anaerobic Running Test

The MART is a maximal exhaustive test consisting of several 20 s bouts of running on a treadmill at a 10.5% gradient with 100 s recovery between bouts. The MART started at a speed of 14.3 $km \cdot h^{-1}$ and increased every bout by 1.2 $km \cdot h^{-1}$ until volitional fatigue (Maxwell and Nimmo, 1996; Rusko et al., 1993). [BLa] measurement was taken immediately after the MART. Maximal anaerobic running performance was calculated using the O_2 equivalents formula for treadmill running ($VO_2 = 3.5 + 12v + 54gv$, where 'v' is the treadmill speed ($m \cdot s^{-1}$) and 'g' is the treadmill gradient expressed as a fraction (American College of Sports Medicine, 2005)). The treadmill speed of the last completed 20 s was used in the calculation. An incomplete bout incurred an additional 1 $ml \cdot kg^{-1} \cdot min^{-1}$ to the anaerobic performance score if at least 10 s was completed and another 1 $ml \cdot kg^{-1} \cdot min^{-1}$ for every 2 s after (Maxwell and Nimmo, 1996; Rusko et al., 1993).

Training Intervention

After pre-intervention testing, participants were matched on their anaerobic performance and then randomly assigned to either a VertiRun group (n=10), overground sprint group (n=10) or control group (n=10). The VertiRun and overground sprint groups undertook the same sprint interval training (SIT) intervention, only the exercise mode differed. The overground sprint group performed sprints 20 m sprint shuttles in a sports hall. The 6-week intervention consisted of 4-6, 30 s all-out efforts separated by 4.5 minutes of low intensity active recovery (RPE 9), 3 times per week. The number of repetitions increased from 4 during week 1-2, 5 during week 3-4 and 6 during week 5-6 (Burgomaster et al., 2008; Whyte et al., 2010). The adherence of participants with the intervention was recorded. Post-intervention MART and VO_{2max} tests were completed within one week of completing the intervention. All participants, including the control group, were asked to continue with their normal activities and dietary habits during the intervention.

Data Analysis

The pre and post-intervention MART and VO_{2max} scores were analysed using a mixed repeated measures ANOVA with Bonferroni pairwise comparisons and Cohen's 'd' effect sizes (ES). Independent t-tests were used to assess for differences in pre-intervention MART and VO_{2max} between groups and adherence of groups to the intervention. Statistical significance was set at $P \leq 0.05$. All statistical analyses were conducted using SPSS (SPSS 23.0.,SPSS Inc., Chicago, IL, USA).

RESULTS

Pre-intervention measures

The pre-intervention participant characteristics of the VertiRun, overground sprint and control groups are shown in table 1. Prior to the intervention, independent t-tests found no difference in the anaerobic or aerobic running performance between the groups as measured by MART (*P*=0.995) and incremental VO_{2max} treadmill test (*P*=0.991), respectively.

Table 1 about here

Adherence to SIT intervention

The VertiRun group completed 93 ± 7% and the overground sprint group completed 92 ± 9% of the total intervention. Independent t-tests found no difference in adherence to the intervention between intervention groups (*P*=0.918).

Pre and post intervention measures

As shown in table 2, repeated-measures ANOVA identified a difference in MART ($F_{(1,27)}$=32.458, *P*<0.001) and VO_{2max} ($F_{(1,27)}$=16.233, *P*<0.001) following the intervention. Group x time interactions were also detected in MART ($F_{(2,27)}$=16.351, *P*<0.001) and VO_{2max} ($F_{(2,27)}$=4.891, *P*=0.015). Bonferroni post-hoc tests identified an increase in MART of 4.5% in the VertiRun group *P*=0.006, ES=0.55), 4% in the overground sprint group (*P*<0.001, ES=0.45) and no change in the control group (*P*=0.910, ES=0.00). The VO_{2max} increased by 6.2% in the VertiRun group (*P*=0.009, ES=0.56), 5.5% in the overground sprint group (*P*=0.020, ES=0.40) and no change in the control group (*P*=0.915, ES=0.143). The increases in MART and VO_{2max} were similar between VertiRun and overground sprint group (*P*=0.647 and *P*=0.358, respectively). Peak [BLa] after the MART and VO_{2max} did not change following the intervention (*P*=0.761 and *P*=0.391, respectively).

DISCUSSION

The aim of this study was to identify the effects of a 6-week SIT programme performed on the VertiRun on aerobic and anaerobic running ability. These results were contextualised by comparison with overground sprint training and a control group. The key findings of this study were that VertiRun exercise increased the anaerobic running performance by 4.5% (MART), and increased aerobic performance (VO_{2max}) by 6.2% with moderate effect sizes. These VertiRun performance improvements were matched by the overground running SIT group, whereas the control group performance was unchanged. Similar increases in running VO_{2max} and MART in both intervention groups suggests that the VertiRun could be an effective cross-training mode and could supplement training for overground running without detriment to running performance.

The key findings of this study concur with previous evidence that there is a degree of transference of physiological adaptations from partial weight bearing and non-weight bearing training exercise to overground running performance (Loy et al., 1994; Millet et al., 2002; Mutton et al., 1993). Direct comparison with previous cross-training literature is difficult because of differences in the exercise modes, frequency, duration, intensity, training status of the participants and the aerobic nature of the intervention. Previous research regarding the SIT intervention used in this study has also reported improvements in aerobic and anaerobic cycling performance. For example, anaerobic performance, as measured by Wingate anaerobic cycle ergometer test, increased by 5.4% (Burgomaster et al., 2006) and 8% (Whyte et al., 2010) following SIT. Under the specificity principle, improvements in anaerobic performance were to be expected since the SIT programme consisted of repeated high intensity, anaerobic bouts and exhaustive exercise. When compared with the 6% increase in VO_{2max} in this study, similar improvements of 6.8% (Burgomaster et al., 2008) and 9.6% (Bayati et al., 2011) have also been reported following the cycle ergometer SIT programme. Despite the anaerobic nature of the exercise periods, aerobic adaptations and improvements were expected because there was a significant demand on the cardiovascular system to support a high aerobic contribution during the rest periods to replenish intramuscular Adenosine Triphosphate and Phosphocreatine in preparation for the next sprint (Burgomaster et al., 2008; Gibala et al., 2006). Literature on SIT cycle training has identified specific physiological adaptations that could underpin the performance improvements for example a 26%-50% increase in resting muscle glycogen after just two weeks of SIT training (Burgomaster et al., 2005; Gibala et al., 2006), increased enzymatic activity (cytochrome c oxidase, citrate synthase, pyruvate dehydrogenase, phosphorylase and 3-hydroxyacyl-Coenzyme A dehydrogenase), increased lipid oxidation to reserve higher order substrates (Burgomaster et al., 2005; Burgomaster et al., 2008; Burgomaster et al., 2006; Gibala et al., 2006), increased H^+ buffering capacity (Burgomaster et al., 2006; Gibala et al., 2006), increase in proportion and cross-sectional area of type II muscle fibres, increased neurotransmitters and subsequent increased motor unit activation and the delaying of neurological fatigue during maximal exercise (Ortenblad et al., 2000). In the research on SIT cycling training, the test mode was specific to the training mode (i.e. cycle exercise) and did not consider the transferability of the physiological adaptations from one exercise mode to another. Whether any of these specific physiological adaptations were responsible for the aerobic and anaerobic improvements following VertiRun and overground sprint training is unclear and requires further research.

A characteristic of the VertiRun is the resistance bands that are tethered to the ankle. Loy et al. (1995) suggested that effective cross-training modes recruit large muscle mass and could condition musculature that was previously untrained. The VertiRun recruits large muscle mass of the lower limbs, especially musculature of the posterior chain (Jordan et al., 2017). In untrained and moderately fit participants, simply training large muscle masses during non-specific exercise could provide a sufficient training stimulus for central and peripheral adaptations to improve overground running performance, however elite athletes require mode-specific training to develop their physical capacities further (Loy et al., 1995; Ruby et al., 1996; Stangier et al., 2016). The targeting of the posterior chain musculature during VertiRun exercise could condition the posterior chain, which is generally under conditioned relative to anterior musculature of the lower limb (Ahmad et al., 2006; Askling et al., 2003). Posterior thigh muscle strength and a rebalancing of the posterior:anterior thigh muscle strength ratio are believed to be significant contributors to running performance (Askling et al., 2003; Bračič et al., 2011; Chumanov et al., 2011) improves running economy (Sundby and Gorelick, 2014) and has been implemented in preventing multiple lower-limb injuries such as hamstring strains and ACL ruptures (Ahmad et al., 2006; Rosene et al., 2001). The conditioning of previously poorly conditioned musculature could reduce the deleterious effects of metabolic acidosis and delay the fatigue of other prominent musculature recruited during overground running (Burgomaster et al., 2006; Foster et al., 1995). In this study, MART and VO_{2max} increased in both VertiRun and overground sprint groups without increases in the peak [BLa] which could be indicative of the musculature sharing the metabolic demand as a result of the SIT intervention.

In cross-training, superior gains in performance have been found when the exercise mode is similar to the test mode (Loy et al., 1995; Tanaka, 1994). The users of the VertiRun undertake a running-like action which is similar to the kinematics and neuromuscular recruitment patterns of overground running (Jordan et al., 2017) and could have facilitated the transfer of adaptations to overground running. The VertiRun is a non-weight bearing exercise mode and therefore athletes could use the VertiRun to increase their training load without the gravity-induced mechanical loading of the lower limbs and risk of overuse injuries that are associated with overground running (Hreljac, 2004; Sobhani et al., 2013). The non-weight bearing nature of VertiRun training, coupled with the training effects identified in this study, suggests that the VertiRun might be also useful in the rehabilitation of lower limb injuries where excessive loading of injured limbs is undesirable. Intense programmes such as SIT might not be appropriate for early rehabilitation stages, however it could be useful in the latter stages to facilitate the physical preparation of athletes returning to sport following a lower limb injury by enhancing aerobic and anaerobic running performance.

Previous studies on cross-training have matched sub-maximal training loads between the non-mode specific and mode specific training to ensure that changes in performance are due to the mode and not the load of the training stimulus (Loy et al., 1994;

Millet et al., 2002; Mutton et al., 1993; Ruby et al., 1996; Wagner et al., 2013). In contrast, the intervention in this study consisted of repeated bouts of maximal intensity VertiRun exercise, rather than continuous sub-maximal exercise, partly due to difficulties in quantifying and subsequently matching the training load between VeritRun exercise and overground sprint training. Differences in the training load and metabolic demands probably existed due to the nature of the exercise modes and posture-related differences between the exercise modes. The sprint group had to support their own body weight, however the metabolic load might have been limited by the relatively low metabolic cost of deceleration phases that are not compensated by the demands of reacceleration in the changing direction of shuttle running (Hader et al., 2016). In contrast, VertiRun exercise is non-weight bearing, however resistance bands tethered to the ankles provided resistance to the musculature of the posterior chain and the 30 s maximal bouts were uninterrupted by changes in direction. Matching training loads based on speed or internal measures such as heart rate and VO_2 would not be valid due to differences in the nature of the exercise modes, anaerobic nature of the training intervention and posture-related differences in the cardiorespiratory system (Billinger et al., 2008; Gronkvist et al., 2002; Jones and Dean, 2004; Prisk et al., 2007; Takahashi et al., 2000) between the recumbent posture of the VertiRun and upright posture of the overground sprint group. Consequently, the training loads between the overground sprint and VeritRun group were not matched stringently and could only be matched on time and that participant efforts were maximal. Although the training load was difficult to quantify in this study, the participants on the VertiRun were able to exercise intensely enough to overload bodily systems and attained changes in running performance to the same degree as mode-specific (overground sprint) training.

In conclusion, six weeks of sprint interval training on the VertiRun improved aerobic and anaerobic running performance. The magnitude of the aerobic and anaerobic improvements were comparable to mode-specific training and suggests that the VertiRun could be an effective cross-training mode for any athlete training to improve running performance. The VertiRun is not intended to replace overground run training because of the beneficial mode-specific adaptations (Loy et al., 1994), however coaches and athletes could supplement their training programmes and benefit from certain characteristics of VertiRun exercise. VertiRun offers a low-impact exercise where athletes could increase their training load to overload bodily systems and attain running specific adaptations without the mechanical loading of lower limbs. Therefore, the subsequent risk of overuse injuries that are common in running-based training (Hreljac, 2004; Sobhani et al., 2013) could be reduced. The VertiRun could also be used to break the monotony of prolonged running training and enhance adherence to a training programme. Furthermore, the nature of VertiRun exercise might enhance other aspects of physical performance that might not be attainable from running training alone, for example the conditioning of undertrained musculature including the posterior chain. Although the training stimulus could not be quantified and the specific physiological adaptations could not be identified, athletes are able to exercise intensely and achieve a sufficient training stimulus for transferrable adaptations for overground running performance.

This study provides a basis for further research on the VertiRun as a cross-training mode. Further research is imperative to provide coaches and athletes with information on the implications of using the VertiRun as a cross-training mode on running and athletic performance. Therefore, future research should focus on identifying the specific physiological adaptations to VertiRun training, including adaptations to sub-maximal VertiRun training interventions, the transference of physiological adaptations to performance in sporting contexts and the use of the sub-maximal VertiRun exercise in the early stages of rehabilitation to maintain fitness and facilitate the return to sport.

CONFLICT OF INTEREST

There are no conflicts of interest.

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Figures

Figure.1. The VertiRun being used in the supine posture and 70˚ posture.

Tables

	VertiRun		Sprint		Control	
Age (years)	22 ± 4		22 ± 3		21 ± 4	
Stature (m)	1.82 ± 0.07		1.79 ± 0.07		1.80 ± 0.10	
Mass (kg)	82.1 ± 5.2		73.2 ± 16.3		80.2 ± 13.1	
	Pre	Post	Pre	Post	Pre	Post
MART ($ml•kg^{-1}•min^{-1}$)	105.2 ± 8.6*	109.9 ± 8.6	104.8 ± 9.3*	108.9 ± 9.2	104.9 ± 7.1	104.9 ± 6.5
MART [BLa] ($mmol•l^{-1}$)	10.4 ± 1.8	10.0 ± 1.3	10.0 ± 1.2	10.4 ± 0.9	10.5 ± 1.7	10.7 ± 2.03
$VO_{2max.}$ ($ml•kg^{-1}•min^{-1}$)	46.8 ± 5.4*	49.6 ± 4.7	47.1 ± 4.5*	49.7 ± 5.3	46.9 ± 4.9	46.2 ± 3.9
$VO_{2max.}$ [BLa] ($mmol•l^{-1}$)	7.2 ± 1.5	7.4 ± 1.2	7.3 ± 1.5	7.2 ± 0.9	8.1 ± 1.3	9.2 ± 2.2

Table 1. Participant characteristics of the VertiRun, overground sprint and control group, the pre and post-intervention Maximum Anaerobic Running Test (MART) and aerobic running power (VO_{2max}) of each group and subsequent peak [BLa]. Values are presented as mean ± standard deviation. * indicates difference between pre and post-intervention (*P*<0.05).