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ORIGINAL ARTICLE

Exercise regulation on lower body positive pressure treadmills: Does body weight % matter

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ABSTRACT

Purpose: This study examined physiological responses between 70% (70) and 90% (90) body weight at RPE of 4 and 7. Methods: Fifteen college-aged participants completed a VO_{2peak} test followed by two experimental sessions, one at 70 and one at 90. The OMNI pictorial RPE scale was used to select LBBPT velocity and grade (participants were blinded to the treadmill screen) to produce RPEs of 4 and 7 at 70 and 90. Following RPE-based intensity selection four, 5-min running bouts assessed physiological responses. Paired samples t-tests determined whether physiological outcomes differed between 70 and 90 at the same RPE. Cohen's d were calculated for all dependent variables. Results: No differences were seen in VO_2 ($p > .05$) at both an RPE of 4 (70 = 25.6 ml/kg/min; 90 = 24.8 ml/kg/min) and 7 (70 = 33.3 ml/kg/min; 90 = 32.1 ml/kg/min), HR at RPE of 4 (70 = 144.1bpm; 90 = 149. 5 bpm) and 7 (70 = 164.3bpm; 90 = 163.4bpm), or RER at RPE of 4 (70 = 0.85; 90 = 0.85) and 7 (70 = 0.93; 90 = 0.93). Conclusion: RPE allowed consistent intensity regulation across lower body weight percentages while exercising on a LBPPT.

Keywords: sport medicine; lower-body positive pressure treadmill; rating of perceived exertion; exercise intensity regulation; body weight support; oxygen consumption; cardiometabolic responses.

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INTRODUCTION

Lower body positive pressure treadmills (LBPPT) are most frequently used in rehabilitation or athlete training settings. Traditionally, overhead harness systems have been used to support body weight, however patients often feel uncomfortable when the overhead system lifts the body, resulting in a reduced training compliance (Lee et al., 2016; Kurz et al., 2011; Grabowski, 2010). Moreover, both harness systems and hydrotherapy create external pressure on the vascular structures of the lower extremities, impairing natural gait patterns and potentially diminishing participant compliance with training protocols (Kristiansen et al., 2019). During exercise the LBPPT uses positive pressure to effectively lift the subject and reduce body weight without restricting lower-extremity circulation, making it a more enjoyable experience (Lee et al., 2016; Barnes & Janecke et al., 2017; Gojanovic et al., 2012). Subjects wear a pair of specialized shorts that zip into the chamber which creates an airtight seal around the lower body and then subjects use the simple interface to select the percent body weight at which they would like to exercise at (Lee et al., 2016; Barnes & Janecke et al., 2017; Gojanovic et al., 2012).

Several studies have assessed physiological and biomechanical responses while using LBPPT. Barnes and Janecke (2017) found that increased body weight support increased stride length and flight duration and decreased stride rate and contact time and overall, the biomechanical changes during LBPPT running contributed to a reduced metabolic cost. Previous research has shown that maximal and submaximal oxygen consumption (VO_2) can be achieved while running on a LBPPT by increasing the velocity to offset the reduction in VO_2 seen with running at different body weight percentages (Barnes & Janecke et al., 2017; Gojanovic et al., 2012; Raffalt et al., 2013; Kline et al., 2015; Gojanovic et al., 2015). During steady state exercise LBPPT has been associated with a reduced cardiometabolic cost, resulting in reductions in heart rate (HR), respiratory exchange ratio (RER), minute ventilation (VE), and rating of perceived exertion (RPE) while exercising at a reduced body weight (Lee et al., 2016; Barnes & Janecke et al., 2017; Gojanovic et al., 2012; Raffalt et al., 2013; Kline et al., 2015; Gojanovic et al., 2015; Farina et al., 2017).

Rating of perceived exertion has been utilized to regulate exercise intensity and has a strong association with HR and VO_2 (American College of Sports Medicine, 2017; Pritchett et al., 2009). Previous research suggests that several physiological and psychological factors contribute to RPE responses such as ventilation, core temperature, lactate, the environment, and knowledge of exercise intensity (Pritchett et al., 2009). McNeil et al. (2015) found that RPE decreased as body weight support increased while running on a LBPPT in elite long-distance runners. Previous studies have shown no differences in RPE with increased body weight support while others have reported increases in RPE with increased body weight support (Gojanovic et al., 2015; Sainton et al., 2015). However, these differences could be due to methodological differences. In the study by Gojanovic et al. (2015), participants performed an incremental exercise test across different levels of body weight support, while Sainton et al. (2015) performed three successive running conditions for 3 min at different levels of body weight support, which could lead to differences in RPE. Hoffman and Donaghe (2011) found that both HR and RPE remained the same for a given VO_2 across different body weights while running on a LBPPT in healthy adults. A study by Green et al. (2002) found that physiological responses during RPE estimation-production correspond better when estimation and production trials are performed at similar treadmill inclines; however, participants failed to accurately regulate intensity at different treadmill inclines (0% vs. 10%). These findings suggest that the modality of exercise is critical for the RPE estimation-production paradigm.

While previous research has shown that RPE can be used to regulate exercise intensity, the efficacy of using RPE to regulate exercise intensity while exercising on a LBPPT remains unknown. This study attempts to fill that knowledge gap by investigating how different body weight percentages affect physiological responses while exercising at an RPE of 4 or 7. Therefore, the purpose of this study examined the physiological responses at 70% (70) and 90% (90) body weight at an RPE of 4 and 7. The study verifies the hypothesis that as percent body weight decreases there are no differences in physiological responses to exercise.

MATERIAL AND METHODS

Participants

Fifteen apparently healthy young adults (11 females and 4 males) between the ages of 18-35 completed the study (Table 1). Participants were aerobically trained (defined as regular physical activity performed at least 3 hours per week) for a minimum of one year. In addition, participants were instructed to refrain from exercise each day they reported to laboratory. Participants completed a physical activity readiness questionnaire (PAR-Q) and those with contraindications to exercise as outlined by the American College of Sports Medicine (2017) were excluded from the study. This study was approved by the Institutional Review Board at the University of Mississippi and all participants provided written informed consent prior to participation in the study. Authors followed the principles as outlined in the Declaration of Helsinki.

Measures

Anthropometric measures

Upon arrival, participants completed an informed consent document, a medical history questionnaire, and a PAR-Q. Participants were fitted with an HR monitor (Polar H10, Stamford, CT) around their chest and were instructed to sit for 5 minutes. After 5 minutes resting, pulse and blood pressure were collected. Height (Stadiometer, Hamburg, Germany) and weight (Digital Scale) were assessed.

Rate of perceived exertion

Participants were then familiarized with the OMNI Pictorial Rate of Perceived Exertion Scale ranging from 0-10. Participants were instructed both verbally and visually that an RPE of "*0*" indicated no feeling of exertion while an RPE of "*10*" indicated maximal exertion (Utter et al., 2004). During testing participants were instructed to hold up their fingers to indicate what RPE they were working at.

VO_{2peak} testing

Participants were fitted for a Hans Rudolph mask and a two-way non-rebreathing valve (Kansas City, MO). Next a graded exercise VO_{2peak} test on a treadmill (Trackmaster Treadmill Full Vision, Fulton, KS) was conducted. The VO_{2peak} test lasted approximately 9-12 minutes. The protocol began at a walking pace (4.82 km/h) at a 0% grade for 2 minutes. Speed was then increased by 1.608 km/h until it reached 14.48 km/h. If peak velocity was reached, grade was increased 2% every minute until volitional exhaustion (Green et al., 2002). Indirect calorimetry (TrueOne 2400, Parvo Medics, Salt Lake City, UT) data was collected and VO_2 was then manually searched for the highest 60s VO_2 average during the final 2 minutes of the test. The Parvo system was calibrated before each participant to the manufacturer's standards.

Procedures

On separate occasions, participants completed LBPPT (Boost Inc, Waukesha, WI) running bouts while metabolic data was collected. The sessions consisted of two 5-min submaximal exercise bouts. Participants ran at an RPE of 4 during one visit and 7 during the other visit. RPE was counterbalanced for visits. The two bouts were completed at 70% or 90% body weight, also counterbalanced. Participants were instructed to adjust the treadmill velocity and inclines to elicit an RPE of "*4*" or "7." The protocol began at 0 km/h, allowing participants one minute to adjust the velocity to either an RPE of 4 or 7. Once RPE was confirmed the 5-min exercise bout began. VO_2, RER, HR, and RPE were collected every minute. The averages of the final 2-min of each 5-min bout were used for statistical analyses. Upon completion of the first running bout participants underwent a 5-min active recovery bout at a pace of 3.21 km/h and grade of 0%. Participants were brought back to 100% of their body weight to eliminate the potential for participants to try to gauge or adjust for the next RPE. Following completion of the active recovery bout the treadmill was adjusted to 70% or 90% body weight and participants were instructed to adjust the treadmill to elicit the remaining RPE level. Once the RPE goal was reached the final 5-min running bout began. The following visit was identical other than the goal RPE.

Analysis

Using SPSS statistical package 30 (SPSS, Chicago, IL) paired samples t-tests were conducted to determine the differences between VO_2, HR, and RER at each RPE level between 70% and 90% body weight. Cohen's d was calculated for all dependent variables and were calculated by taking the differences in means divided by the pooled standard deviation. A small effect was seen as 0.2, a medium effect as 0.5, and a large effect as 0.8 respectively (Cohen, 1988). Significance was declared at $p < .05$ and all data is presented in means ± standard deviations (SD).

RESULTS

Participant demographic variables are presented in Table 1. Treadmill grade was significantly higher ($p < .05$) at an RPE of 4 ($p = .013$) and 7 ($p = .007$), however treadmill speed was not different ($p > .05$) between an RPE of 4 ($p = .087$) and 7 ($p = .170$) (Table 2). Cohen's d revealed there to be a large effect for grade at an RPE of 7 (Cohen's $d = 1.07$) and a medium effect at an RPE of 4 (Cohen's $d = 0.65$) (Table 2). For speed, Cohen's d revealed a medium to large effect at an RPE of 4 (Cohen's d = 0.70) and a small to medium effects at an RPE of 7 (Cohen's d = 0.48) (Table 2). There were no significant reductions in VO_2 at an RPE of 4 ($p = .388$) and 7 ($p = .387$) with trivial to small effect sizes (Cohen's d = 0.07; Cohen's d = 0.24) (Figure 1; Figure 2). HR was not significantly different at an RPE of 4 ($p = .312$) or 7 ($p = .899$), with a small effect at an RPE of 4 (Cohen's d = 0.33) and a trivial effect at an RPE of 7 (Cohen's d = 0.01) (Figure 3; Figure 4). There was no significant difference in RER at an RPE of 4 ($p = .906$) or 7 ($p = .885$) with trivial effect sizes at both levels (Cohen's d = -0.08; Cohen's d = -0.04) (Figure 5; Figure 6). Cohen's d revealed there to be.

Table 1. Participant demographics (n = 15; mean ± SD).

Age (years)	21.2 ± 1.42
Weight (kg)	66.37 ± 11.78
Height (cm)	170.73 ± 6.99
VO_{2peak} (ml/kg/min)	43.45 ± 6.43

Note. kg = kilograms; cm = centimetres; ml = millilitres; min = minute.

Table 2. Treadmill grade and speed at RPEs of 4 and 7 (n = 15; mean ± SD).

	70% BW	90% BW	*p*-value	Cohen's d
Speed (RPE 4) (km/h)	9.41 ± 2.48	8.05 ± 1.26	.087	0.70
Grade (RPE 4)	0.80 ± 1.08	0.25 ± 0.51	.013	0.65
Speed (RPE 7) (km/h)	12.63 ± 1.92	11.60 ± 2.35	.170	0.48
Grade (RPE 7)	4.17 ± 4.08	0.93 ± 1.33	.007	1.07

Note. RPE = rating of perceived exertion; km = kilometre; h = hour; BW = body weight.

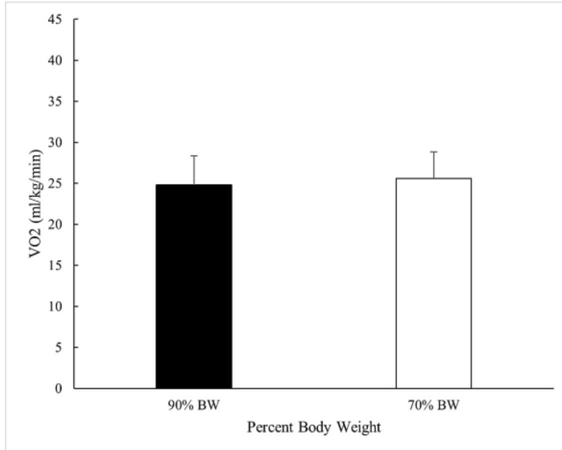

Figure 1. Comparison of VO_2 at an RPE of 4 at 90% and 70% BW. VO_2 was not significantly lower between 90% and 70% BW at an RPE of 4. * Indicates significance at $p < .05$, BW = body weight.

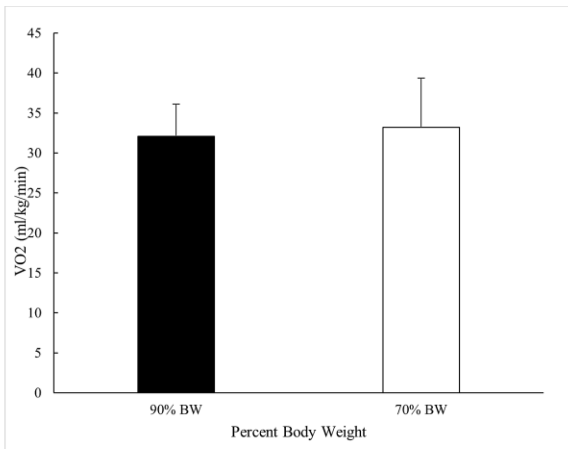

Figure 2. Comparison of VO_2 at an RPE of 7 at 90%, and 70% BW. VO_2 was not significantly lower between 90% and 70% BW at an RPE of 7. * Indicates significance at $p < .05$, BW = body weight.

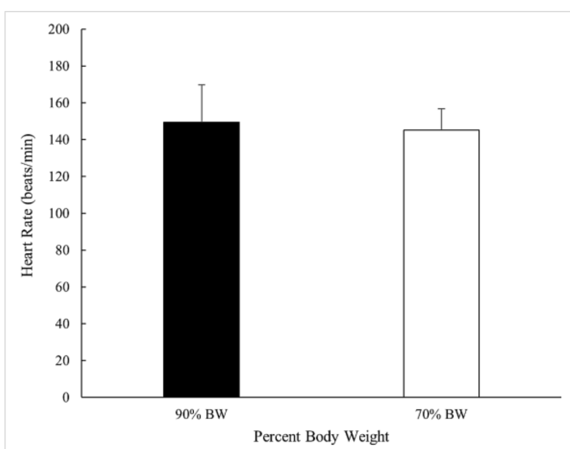

Figure 3. Comparison of HR at an RPE of 4 at 90% and 70% BW. HR was not significantly lower between 90% and 70% at an RPE of 4. * Indicates significance at $p < .05$, BW = body weight.

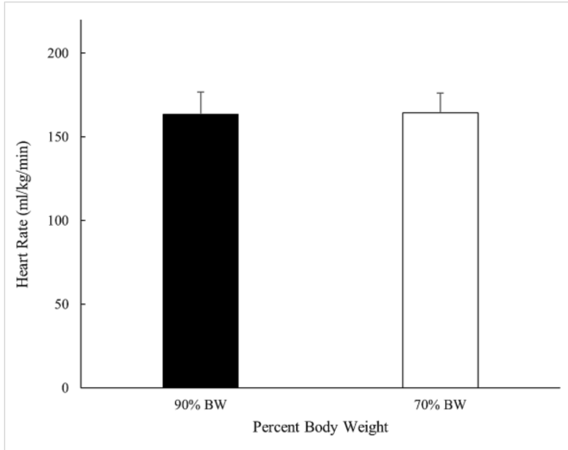

Figure 4. Comparison of HR at an RPE of 7 at 90%, and 70% BW. HR was not significantly lower between 90% and 70% BW. * Indicates significance at $p < .05$, BW = body weight.

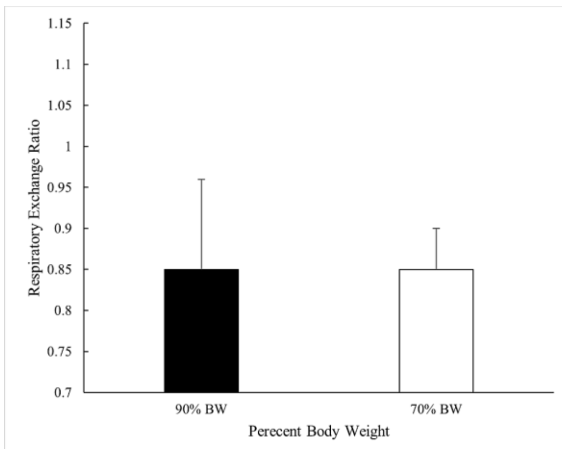

Figure 5. Comparison of RER at an RPE of 4 at 90% and 70% BW. RER was not significantly different between 90% and 70% BW at an RPE of 4. * Indicates significance at $p < .05$, BW = body weight.

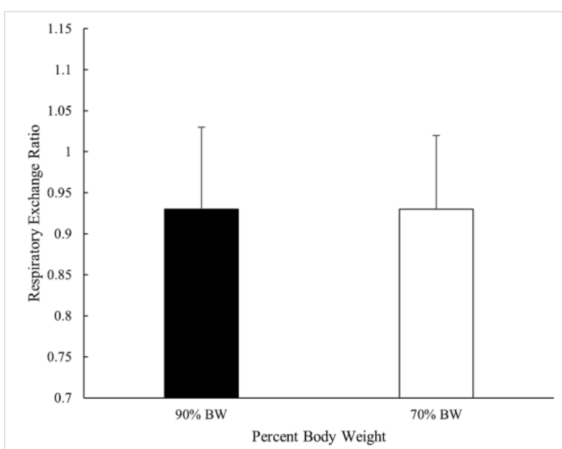

Figure 6. Comparison of RER at an RPE of 7 at 90% and 70% BW. RER was not significantly lower between 90% and 70% BW at an RPE of 7. * Indicates significance at $p < .05$, BW = body weight.

DISCUSSION AND CONCLUSIONS

This study aimed to examine the efficacy of RPE based exercise intensity and the physiological responses at reduced body weight loads. While previous research has examined the physiological and biomechanical effects of LBPPT, this is the first study to test whether RPE can regulate exercise intensity across different levels of body weight support. The principal finding was that participants self-regulated exercise intensity independent of mechanical loading. Despite a 20% difference in body weight support, VO_2, HR, or RER did not differ at either an RPE of 4 or 7 (Figure 1 – 6) and the corresponding effect sizes were trivial to small (Cohen's d = -0.08 – 0.33) further indicating physiological stability. Treadmill grade increased significantly to compensate for the reduction in mechanical loading, with a large effect at an RPE of 7 (Cohen's d = 1.07) and a medium effect at an RPE of 4 (Cohen's d = 0.65). Treadmill speed did not differ significantly between conditions, but the associated effect sizes were medium to large (Cohen's d = 0.70 at an RPE of 4; d = 0.48 at an RPE of 7) indicating that speed may also have contributed to the reduction in mechanical loading and the non-significant result may reflect limited statistical power rather than a true absence of change. Taken together, these findings suggest that RPE functions as a load-independent regulator of internal exercise intensity on a LBPPT with changes in treadmill grade and potentially speed rather than changes in cardiometabolic strain compensating for the differences in body weight support.

This aligns with the conceptual model of perception-based intensity regulation, in which RPE integrates central and peripheral physiological cues (ventilation, core temperature, lactate accumulation) with both situational and psychological information to guide intensity regulation rather than tracking mechanical or metabolic data (Pritchett et al., 2009; American College of Sports Medicine, 2017). An increase in body weight support reduces the mechanical demand of running, which may lead to reductions in the physiological demand while exercising on a LBPPT. In the current study, as body weight support increased, participants appeared to adjust by increasing the treadmill grade and to a lesser extent velocity, until perceived effort matched the target RPE. This resulted in no differences in physiological strain (VO_2, HR and RER) between body weight conditions (70% and 90%) (Figure 1 – 6). These results align with and extend prior work on the RPE estimation-production paradigm. Previous research has shown that VO_2 is more accurately estimated by RPE compared to HR, however, using HR and RPE together yield a more accurate estimation-production (Morgan et al., 1981; Noble et al., 1982). Furthermore, RPE estimation is a valid method of regulating exercise intensity when estimation and production occur within the same exercise modality (Ceci et al., 1991; Dunbar et al., 1992; Stoudemire et al., 1996). Kang et al., (2003) reported no difference in RPE estimation-production accuracy between treadmill and cycle ergometer exercise, while Green et al., (2002) found that HR and VO_2 during level-ground production were significantly lower than during incline (10%) production. This may suggest that the estimation-production relationship is sensitive to changes in exercise modality. Unlike the modality shifts, changing the body weight support did not disrupt the RPE estimation-production relationship in the current investigation.

The current findings should be considered alongside prior LBPPT literature, most of which has compared reduced body weight conditions to full (100%) body weight rather than comparing two reduced weight conditions directly. Prior investigations have shown reductions in VO_2, HR, RER, and cardiometabolic cost as body weight support increases relative to 100% body weight (Lee et al., 2016; Grabowski et al., 2010; Kristiansen et al., 2019; Barnes & Janecke, 2017; Gojanovic et al., 2012; Raffalt et al., 2013; Kline et al., 2015; Gojanovic et al., 2015; American College of Sports Medicine, 2017). McNeil et al. (2015) reported reductions in RER at body weight supports of 20% and 40% at increasing running velocities, while Barnes and Janecke (2017) found trivial-moderate reductions in RER relative to body weight support. Additionally, Lee et al. (2016) observed reduced peak HR with increasing body weight support but no differences between

40%, 60%, and 80% support conditions. Gojanovic et al. (2012) assessed VO_{2max} across different levels of body weight support and found no differences in VO_{2max} between the different levels of body weight support (100%–85%), although peak velocity was lower on a normal treadmill than on the AlterG treadmill. The current study examined the physiological differences between two different reduced body weights and found that both 70% and 90% of body weight produced similar physiological responses while exercising at an RPE of 4 and 7. Additionally, the velocity at which the participants ran did not differ between body weight support or RPE level, but treadmill grade was significantly higher at 70% body weight at both an RPE of 4 and 7 (Table 2). These results suggest that grade adjustments are sufficient to offset reduced mechanical loading and preserve stable cardiometabolic responses. This could be particularly useful for clinicians, strength and conditioning coaches, and athletic trainers to reduce external loading while internal loading remains the same. Future research should investigate repeated bouts at an RPE of 4 and 7 at different percentages of body weight to fully support this claim.

The current findings have practical relevance across several user groups. For clinicians, utilizing LBPPT in rehabilitation populations who are unable to tolerate high impact loading, RPE estimation-production is a simple way to prescribe exercise intensity without having to rely on cardiometabolic values each time body weight support is adjusted between 70% and 90%. Strength and conditioning coaches, and sport scientists could use RPE to standardize training intensity during return to play protocols since body weight support is often increased incrementally as the athlete regains strength. Additionally, coaches and sport scientists monitoring training load on a LBPPT using RPE should track both treadmill grade and velocity rather than relying on body weight percentage alone when comparing exercise sessions performed at different support levels.

This study is not without limitations. The wide range of individual fitness levels among participants may have contributed to inter-individual variability in RPE responses. However, every participant participated in a minimum of three hours of aerobic exercise per week for a minimum of one year. Furthermore, RPE estimation-production was assessed only on a LBPPT, so these findings may not generalize to other weight-supported exercise modalities. Additionally, the sample size (n = 15) is relatively small and may reflect type II error rather than an absence of effect. Nonetheless, the sample size is consistent with prior LBPPT research reporting physiological data (McNeil et al., 2015; Grabowski et al., 2010; Kristiansen et al., 2019; Kline et al., 2015; Gojanovic et al., 2012; Barnes & Janecke, 2017; Lee et al., 2016). Lastly, the sample population was limited to young, aerobically trained adults (Table 1), which limits generalizability to other populations such as older adults, clinical or rehabilitation populations, or individuals with lower fitness status.

In conclusion there were no differences in cardiometabolic responses when using RPE-based exercise intensity at reduced body weights of 70% and 90% on a LBPPT. Treadmill velocity remained relatively the same between the trials, but treadmill grade was significantly higher at 70% body weight at both an RPE of 4 and 7. These results support the use of RPE as an exercise intensity regulator and suggest that clinicians, strength and conditioning coaches, and sport scientists can use RPE to prescribe and monitor LBPPT exercise at 70% and 90% body weight support, provided that treadmill grade and speed are also tracked. Future research should incorporate additional physiological variables such as blood lactate, minute ventilation, and neuromuscular measures to provide a more comprehensive understanding of the mechanisms during RPE based intensity regulation during LBPPT exercise.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows:

Conceptualization: Trace A. Dominy, Dr. Thomas L. Andre, Dr. Julia P. Phillips, and Dr. Silvio Valladao. Methodology: Trace A. Dominy, Camille Couey, Dr. Thomas L. Andre, Dr. Julia P. Phillips, and Dr. Silvio Valladao. Formal analysis: Trace A. Dominy. Investigation: Trace A. Dominy, Camille Couey, Dr. Julia P. Phillips, Dr. Valladao, Dr. Kaitlyn Armstrong, Dr. Thomas L. Andre. Data curation: Trace A. Dominy and Dr. Eric K. O'Neal. Writing – original draft: Trace A. Dominy and Camille Couey. Writing – review & editing: Trace A. Dominy, Camille Couey, Dr. Julia P. Phillips, Dr. Silvio Valladao, Dr. Eric K. O'Neal, Dr. Thomas L. Andre. Supervision: Dr. Thomas L. Andre.

All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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