A Systematic Review on the Effectiveness of Active Recovery Interventions on Athletic Performance of Professional-, Collegiate-, and Competitive-Level Adult Athletes

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Abstract

Ortiz Jr, RO, Sinclair Elder, AJ, Elder, CL, and Dawes, JJ. A systematic review on the effectiveness of active recovery interventions on athletic performance of professional-, collegiate-, and competitive-level adult athletes. *J Strength Cond Res* 33(8): 2275–2287, 2019—Active recovery (AR) is a popular approach to enhancing athlete recovery from participation through physical action, and it has a perceived benefit in the recovery of athletes' enhancement of postexertional physiological status; however, it is unclear whether these recovery techniques enhance athletic performance. The purpose of this systematic review was to examine the effects of AR interventions conducted postexertion on athletic performance among professional, collegiate, and competitive adult athletes. Articles were collected via 4 online databases restricted to publication in English between 1998 and 2014. After the evaluation of overlap among the databases and abstract review, 150 potential eligible studies remained. Twenty-six articles involving 471 subjects remained after full analysis. The primary exclusion factor was absence of AR types of interest or measures of performance. The review resulted in a wide variety of findings indicating the vagueness in AR approach and outcome measures, making it difficult to draw specific conclusions. The review demonstrated that AR interventions lasting 6–10 minutes revealed consistently positive effects on performance. The appropriate intensity level of AR sessions was inconclusive in the literature; however, blood lactate clearance rate as a recovery marker appeared unreliable. The review suggests that there are positive psychological outcomes from AR sessions, a need to determine if AR should be individualized in its application, and weak evidence regarding the efficacy of postexercise AR, particularly relating to performance. Future research is needed for reliable and accurate markers for fatigue, physiological recovery, performance, and markers of intensity and duration for AR interventions.

Key Words athlete, athlete recovery, sports performance

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33(8)/2275–2287

Journal of Strength and Conditioning Research

Introduction

Strenuous training regimens combined with condensed competition schedules often hinder physical recovery among athletes (19). As such, postexercise interventions intended to facilitate or enhance athlete "recovery" have become popular to reduce the risk of performance decrements and overtraining (4,8). Active recovery (AR) is a commonly used technique that includes a variety of submaximal activities, such as running, jogging, cycling, swimming, or active stretching, with the intention to facilitate or enhance postexertion physiological recovery (4,26). Additionally, other types of AR techniques exist including cold-water immersion (CWI), massage, contrast water therapy (CWT), electromuscular stimulation, and the use of compression garments during exercise (4,13,36).

Since the early 1980s, strategies such as AR have been implemented with the objective of maximizing athletic performance via rapid physiological revitalization (4,7,8). It is thought that AR assists athletes during a postexercise recovery period by facilitating return to physiological homeostasis (20,26,34). This expedited recovery process involves increased rates of intramuscular blood flow subsequently enhancing blood lactate (BLA) removal and skeletal muscle energy levels, although decreasing the duration and severity of exercise induced delayed onset muscle soreness and skeletal muscle injury (2,20,26).

Active recovery activities are designed to cause a dynamic shift away from stress-induced metabolic disturbances and toward physiologic recovery in any athlete undertaking regular physical training (31). The perceived advantages of AR has on athletic performance include allowing an athlete to consistently tolerate higher training loads (intensity, frequency, or cumulative volume) (4,17,26,30), positively influencing an athlete's psychological perception of musculoskeletal recovery (1,5,6,13,19,28), and facilitating return, or near return, to physiological homeostasis before subsequent exertions (4,17,26,30). However, it is not clear whether AR interventions conducted postexercise influence the athletic performance of competitive adult athletes because there has been no collective analysis of the AR literature. Therefore, the purpose of this systematic review was to examine the effects of AR interventions conducted postexertion on athletic performance among professional, collegiate, and competitive adult athletes.

Methods

Experimental Approach To Problems

Articles were collected in October 2015 via online databases, including MEDLINE, PEDro Database, PubMed, and SPORTDiscus. The search was restricted to articles published in the English language between 1998 and 2014, available in full text, and using human subjects. Key words, EBSCO thesaurus, and MeSH terms were used to enhance the search process. Key words related to the research question included *active recovery and recovery exercise*, whereas key words relating to the subject population included *sports, athletics*, and *performance*. No key words for comparison or outcome measures were used.

Subjects

The forms of AR considered included varying combinations of submaximal activities conducted postexercise, such as running, jogging, cycling, swimming, and active stretching techniques. In addition, performance parameters that were considered included increases in speed, agility, power, and time to fatigue of athletes exposed to AR. The study was approved by the University of Colorado in Colorado Springs.

Procedures

The primary and secondary researchers independently screened all articles that "hit" during the search for inclusion in the study based on the inclusion and exclusion criteria. Articles were initially screened based on the available information in the title and abstract (20). Any articles duplicated in multiple databases were noted and excluded from the overall count. The 2 researchers compared their findings, discussed any discrepancies, and then performed a secondary independent screening using the full-text version to further determine if the article met the inclusion criteria. A final meeting was held to make the final determination of which articles would be included in the review. The final selection of articles were screened for bias through the lack of randomization or blinding, disclosure of conflicts of interest or financial contributors, significant selection biases, confounding variable bias, and a lack of prospective study designs. Final articles were also screened for quality assessment using the Oxford Center of Evidence Based Medicine (OCEBM) Level of Evidence Scale (24). The OCEBM scale classifies studies as levels 1 or 2 that possess stronger or higher levels of evidence, whereas studies rated levels 3, 4, or 5 as weaker or lower levels of evidence.

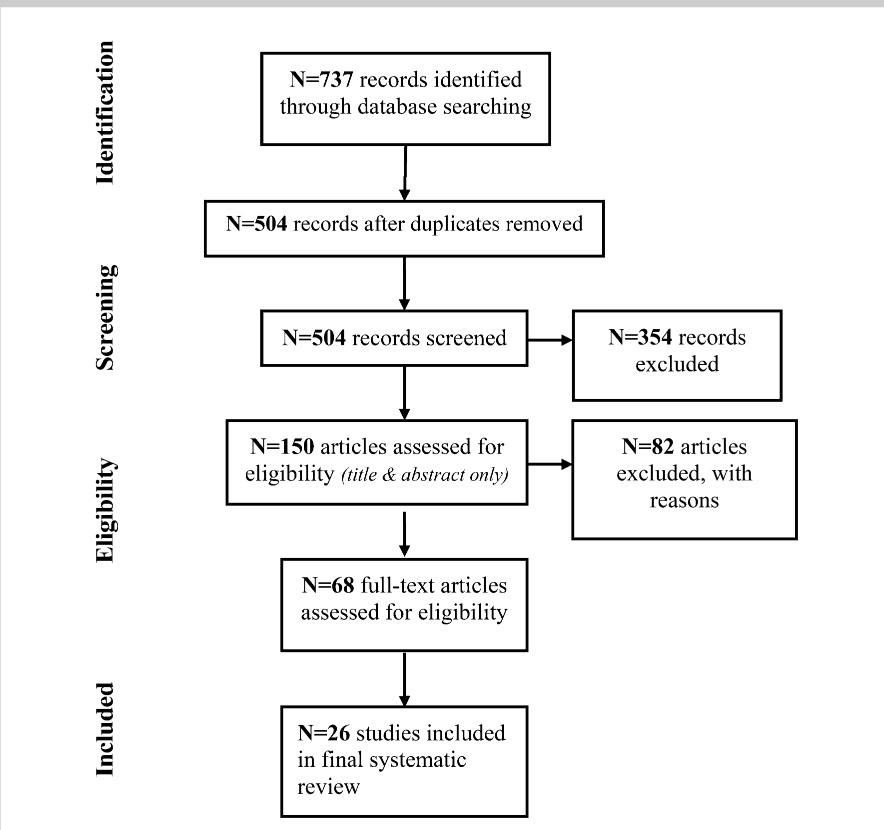

Figure 1. Summary of the systematic review.

Results

Initial search results yielded 737 articles, 150 of which were considered relevant after initial examination of the abstracts and titles. Upon further examination by both researchers, it was determined that of 150 potential articles, 26 met the criteria for inclusion in the final review. Figure 1 provides a summary of the systematic review screening process and outcomes.

Table 1. Summary of article characteristics.*

Author	Subjects (*N*; gender) and athletic level	Treatment; recovery	Outcome measures	Results	Level of evidence
Studies using single AR variables					
Ali Rasooli et al. (1)	(17; M) Pro swimmers	200 m max front crawl swim separated by 10-min of interval recovery period (AR, PR, or massage); 200 m of front crawl swim with 65% effort, sitting, 10 min massage	BLA; 200-m swimming performance	AR was more effective than massage, and massage was more effective compared with PR in removing BLA. AR and massage were moreeffective in improving swimming performance compared with PR	4
Andersson et al. (2)	(22; F) Pro Swedish soccer	2 soccer matches followed by AR and PR; 60% MaxHR cycling and 50% 1RM resistance training	CMJ; spring performance; max isokinetic knee flexion/ extension; creatinine kinase; urea; ureic acid; perceived muscle soreness	AR had no effect on recovery pattern for any of the outcome measures	2
Bosak et al. (6)	(9; M 3; F) Well-trained runners	72 hrs of AR or 72 hrs of PR after a 5-km running performance; two 65–75% MaxHR 5-min run	Mean 5-km time; average HR, RPE	Mean finishing times did not differ significantly between AR and PR; Average HR was significantly lower for AR; RPE was significantly higher for PR and did not differ from AR	4
Dupont et al. (11)	(12; M) Specialized soccer	3-sessions of 2 sprints. Recovery between 2 tests was 15 sec of either AR or PR; pedaling at 20 or 40% aerobic power	Mean power, peak power of WAnT performance; change in oxyhemoglobin and deoxyhemoglobin	Mean and peak power of postrecovery WAnT and deoxyhemoglobin were significantly higher with PR than either AR condition	3
Franchini et al. (12)	(37; M) Competitive judo	Incremental treadmill test and judo match followed by AR or PR and performance task; 50% $\dot{V}O_2max$	BLA, peak power, mean power, fatigue, time to peak power	AR reduced BLA levels > PR. Neither AR nor PR affected subsequent performance	4

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Greco et al. (13)	(19; M) Trained cyclists	Cycle ergometer incremental or CWRT to determine work rate at (MLSSwcont) orr intermittent (MLSSwint) with AR and PR; 50% PV_{O_2} cycling	BLA, work rate at MLSSwint and MLSSwcont	MLSSwint was significantly higher than MLSSwcont for both PR and AR; AR did not have a significant effect on work rate during prolonged intermittent exercises	4
Greenwood et al. (14)	(14; M) NCAA D1 swimmers	200-yard max-effort swim followed by 10 min of AR or PR and a 200-yard max effort swim; V_{LT}, 50% V_{LT}, and 150% V_{LT} swimming	BLA, performance time	For all subjects AR at or 1.5× above V_{LT} improved performance time more than PR; All AR conditions resulted in significant decrease of BLA, with greatest at V_{LT}	2
Jemni et al. (17)	(12; M) Gymnasts	6-Olympic events separated by 10 min of PR or PR + AR combined; self-selected most including light running and tumbling at or below V_{LT}	BLA; performance value (change from start value to actual score)	Gymnasts showed higher BLA concentration and significantly higher scoring performances with combined PR + AR recovery between events	2
Jougla et al. (18)	(7; M) Rugby	Repeated-sprint rugby Narbonne test pre and post 30-min rugby match w/30 sec PR or AR. Test completed; running 50% max speed	RPE, mean HR, scrum force, agility/sprint time, HR, fatigue index.	No difference in scrum force, RPE Scrum and sprint HR, sprint time significantly higher in AR group PR enabled better outcomes in rugby specific exercises	3
Lau et al. (21)	(19; M) NCAA D1 Hockey	Skating tests pre and post 15-min AR or PR; low-intensity cycling	Distance skated, HR, BLA	PR vs. AR showed no significant differences for distance skated, HR, or BLA. AR did not enhance BLA removal or subsequent performance of repeated work bouts in simulated hockey play	2

Ouergui et al. (25)	(18; M) Sporting club kick boxers	10-minute treadmill run at 50% of maximal aerobic speed or PR conducted after 3-round kickboxing match	BLA, HR, RPE, upper-body Wingate, squat jump, CMJ	AR significantly decreases BLA after match, whereas PR resulted in significantly higher mean power after 10 min of recovery. Jump performance did not change with AR or PR	4
Rey et al. (28)	(31; M) Pro soccer	Standardized soccer training with 20-min AR or PR; submax running and static stretching	Muscle contractile properties using TMG, HR, RPE, and perceived muscle soreness	AR after soccer training had no significant effect on TMG, HR, RPE, or muscle soreness compared with PR	2
Rey et al. (27)	(31; M) Pro soccer	Standardized soccer training with 20-min AR or PR; submax running, and static stretching	HR, RPE, lower-limb flexibility, CMJ, 20-m sprint time, agility	Significantly increased CMJ posttest values were found with the AR group. Neither AR or PR effected flexibility, sprint time, agility, RPE, or HR	2
Toubekis et al. (35)	(9; M) Elite swimmers	8 reps of 25-m sprints combined with 45-sec PR or AR intervals, followed by a 50 m-sprint test 6 min later; 50 and 60% of 100-m swim velocity	BLA, 50-m sprint test, estimated energetic cost	AR at intensities of 50% and 60% of 100-m velocities during repeated swimming sprints decreased performance. BLA and was significantly higher for PR; sprint time was significantly better with PR, but performance on a 50-m sprint was not affected when 6 min recovery was provided	3
Toubekis et al. (33)	(8; M) Elite swimmers	3 trials of 2 sets of front crawl swims with 5-min rest between sets; 60% front crawl pace	BLA, blood pH, performance time	AR could be beneficial between training sets and may compromise swimming performance between reps when recovery durations are short ($<$2 min)	3

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Watts et al. (37)	(15; M) Rock climbers	20 m difficult route set on an indoor climbing wall followed by AR or PR; 25 W recumbent cycling	$\dot{V}O_2$, BLA, handgrip strength	BLA returned to baseline levels 10 min faster with AR than PR. AR induced greater amount of decreased grip strength compared with PR, although not statistically significant	4
West et al. (38)	(36; M) Pro rugby	Baseline CMJ followed by PAP stimulus with 8 min of AR or PR followed by posttest CMJ; 30% 1RM bench press after PAP	CMJ PPO	PR and AR both increased CMJ PPO, but PR resulted in greatest change in performance; AR is better when more exercises need performed.	2

Author & year	Subjects (N; gender) and athletic level	Treatment	Outcome measures	Results	Level of evidence
Studies utilizing multiple active recovery Variables					
Bahnert et al. (3)	(45; M) Pro rugby	AR modalities post game across season; self-selection from a variety of recovery modalities categorized by stretching, physical activity, hydrotherapy, or compression garments	Vertical jump performance, and recovery perception scale, coach vote of performance	Vertical jump was not related to recovery choice. A variety of modality combinations significantly improved recovery perception. There was no impact on performance	3
De Pauw et al. (9)	(17; M) Cyclists	1 hr of cycling at different intensities. After TT1 20 min AR, PR, or CWI followed by TT2. 15-min recovery of PR, AR, leg cooling and compression or AR + cooling or compression; 80 W cycling	TT performance, BLA removal. TT performance, BLA, RPE, thermal comfort, rectal temperature, skin temperature	AR, PR, and cooling or compression had no significant performance effect during TT2; AR + cooling or compression decreased BLA better than AR alone	2

De Pauw et al. (10)	(9; M) Trained cyclists	1 hr 55% Wmax followed by 30-min TT, followed by 15-min recovery of PR, AR, CWI, followed by TT2; 80 W cycling	BLA, HR, RPE, thermal stress, rectal temperature, skin temperature	No significant TT2 performance differences were found; CWI had consistent pacing, where AR and PR showed gradual pacing decline; AR and CWI trended toward faster BLA removal	4
Hamlin MJ (15)	(17; M 3; F) Competitive rugby	Ten 40-m sprints with 30-sec rest. CWT or AR applied after sprints. Test repeated 1 hr later; 6-min slow jogging	Sprint time, BLA, HR	Compared with AR, CWT decreased BLA concentration and HR but has little effect on subsequent repetitive sprint performance; both AR and CWT resulted in decrease in sprint time	3
Heyman et al. (16)	(13; F) Rock climbers	2-rock wall climbing tests until exhaustion on a prepracticed route. Tests separated by 20 min of AR, PR, CWI, EMS; 30–40 W cycling	Climb duration, BLA, HR, RPE, skin temperature, grip strength	AR and CWI maintained performance levels, while significantly reducing BLA levels and tissue temperatures; PR and SWI decrease performance; grip strength, HR, RPE were not affected by recovery modality	2
King and Duffield (19)	(10; F) Competitive netball	4- simulated netball exercise circuits on consecutive days followed by AR, PR, CWI, CWT	Vertical jump, 20-m sprint, 10-m sprint, circuit time, BLA, RPE, muscle soreness	AR recovery caused elevated RPE ratings, muscle soreness, and HR. No significantly different differences on performance were found between recovery modalities	2

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Malone et al. (22)	(13; M) Triathletes	Three 30-sec WAnT bouts followed by a randomly assigned 30-min AR, PR, or NMES recovery session, and 3 WAnT bouts; 30% Max $\dot{V}O_2$ cycling	Peak power, mean power, fatigue index, BLA, HR	AR significantly decreased BLA levels more than NMES and PR; peak and mean power, and fatigue did not improve significantly for either recovery type; NMES did not appear to be more effective than AR or PR for enhancing short-term recovery	2
Monedero and Donne (23)	(18; M) Cyclists	2-simulated 5-km max effort cycling tests separated by a 20-min recovery of AR, PR, massage, or cycling + massage combination; 50% $\dot{V}O_2$max cycling	BLA, performance time	Combined recovery was significantly better in maintaining performance time; AR significantly improved BLA removal at 9 and 12 min after treatment.	2
Warren et al. (36)	(7; M) NCAA D2 Pitchers	Designated AR, PR, or EMS used between innings for 3 innings of a simulated game; 60% maxHR jogging	RPE scales, BLA, pitching performance	EMS significantly decreased BLA levels and RPE ratings greater than AR and PR; pitching speeds were lower with AR	4

*AR = active recovery; Ath = Athlete; BLA = blood lactate; CMJ = counter movement jump; CWT = contrast water therapy; CWI = cold water immersion; CWRT = submaximal constant work rate test; D, Division; EMS = electromuscular stimulation; F = Female; HR = heart rate; Hr = Hour(s); M = Male; m = Meter(s); MaxHR = max heart rate; Min = Minute(s); MLSSwcont = max lactate steady state continuous; MLSSwin = max lactate steady state with intervals; N = number of subjects; NCAA, National Collegiate Athletic Association; NMES = neuromuscular electrical stimulation; PAP = post activation potentiation; PR = passive recovery; PPO = peak power output ; Rand = Randomized; RCT = randomized controlled trial; RM = repetition maximum; RPE = ratings of perceived exertion; Sec = seconds; TMG = tensiomyography; TT = time trial; VLT = lactate threshold; W = Watts; WAnT = Wingate test; WK = week; Wmax = work max; > = greater than; < = less than; level of evidence based on Center for Evidence Based Medicine Scale (1 is highest quality RCT down to 5 which is expert opinion).

The 26 included studies were separated into 2 separate categories for review based on the number of recovery techniques used as variables, either single or multiple techniques, within each respective study (single, $n = 17$ or multiple, $n = 9$). The total number of subjects involved was 471.

The OCEBM (24) ratings for single recovery studies included 7 level 2, 4 level 3, and 6 level 4 studies; the multiple recovery studies included 5 level 2, 2 level 3, and 2 level 4 studies. No bias issues were found. Throughout this review, outcome measures used in the studies varied only slightly, whereas intervention type, intervention number, subject characteristics, and sport varied greatly among studies. Additionally, there was large variation regarding physiological and performance markers used throughout the studies. This methodological variation potentially explains the inconclusive results found across the included studies. Table 1 summarizes the study design, participant characteristics, intervention, and outcome measures of all studies included in this review.

Discussion

The purpose of this review was to determine the effectiveness of AR interventions on the athletic performance of professional, collegiate, and competitive adult athletes through a systematic review of the literature. Current research has primarily focused on the physiological effects of AR and its effect on muscular recovery in subjects of varying athletic levels and populations. However, up to this point, there has been no collective analysis of the AR literature. As a result, no general consensus currently exists regarding the efficacy of AR or its potential effects on athletic performance. Therefore, it was imperative to conduct an analysis of the literature to determine if the commonly used recovery strategy of AR is actually an effective recovery strategy with the potential to effect athletic performance.

Among the reviewed studies, duration of the AR sessions was variable among the studies. First, outcomes from 7 single-recovery studies indicate that the duration of an AR recovery period ranging from 6 to 10 minutes in total length appears to have a positive effect on athletic performance, with increases in muscular BLA removal and increased sport-specific performance metrics (e.g., counter movement jump [CMJ] posttest values and timed swim times) (1,13,14,17,27,33,38). Each of the 7 studies used a wide variety of AR interventions, such as 5 minutes of light running (17), 60% mean speed of athlete's 100-m swim time (22), or varying percentages (0, 50, and 150%) of athlete's lactate threshold (13,14). Despite the varying AR protocols, participant populations, and physiological recovery and performance markers, all 7 studies reached the same conclusion: AR has a positive effect on athletic performance (1,13,14,17,27,33,38). Positive performance metrics attributed to the utilization of AR in these studies included increased levels of BLA removal measured via collected blood samples (1,17,33) and increased sport-specific performance outcomes (e.g., increased CMJ posttest values, faster post-AR intervention swim times, and increased gymnastic scores post AR intervention) (13,14,27,38).

Alternatively, 8 studies of differing quality examined various AR interventions of moderate (10 minutes to 72 hours) and short (30 seconds to 2 minutes) durations (2,6,13,18,21,25,28). The results of these studies suggest that AR interventions of both moderate and short duration had no or negative effects on athletic performance or associated recovery (2,6,12,13,18,21,25,28). The repeated absence of methodological homogeneity among AR investigations underscores the variability that currently exists in approaches commonly taken to implement AR interventions and impeding the understanding of the efficacy of AR.

Similar to the single recovery studies, the multiple-recovery studies by Bahnert et al. (3), King et al. (19), and DePauw et al. (9) agreed that AR interventions of longer duration (8–15 minutes) had no effect on athletic performance or associated recovery.

Each individual AR intervention listed in the study of Bahnert et al. (3) varied in total duration from 8 to 12 minutes. Activities, such as floor and pool stretching, bike AR, pool AR, and CWI, all used an 8-minute intervention duration, whereas CWT required athletes to use contrast water baths for a total duration of 12 minutes. DePauw et al. (9) reached similar conclusions while using a 15-minute intervention period consisting of cycling against 80 watts of resistance. Before the AR intervention, subjects completed a 1-hour constant load cycling trial at 55% of their work maximal aerobic capacity (MAC) followed by a 30-minute simulated time trial. After the 15-minute AR intervention, a second, 30-minute, simulated time trial was conducted. Despite methodological differences, all 3 studies (3,9,15,19) agreed with previous research (2,6,12,18,21,25), which indicated that prolonged periods of AR postexercise negate the physiological benefits of AR that are perceived to have a direct positive effect on athletic performance (3,9,15,19). The results of the studies by Hamlin et al. (15), King et al. (19), Bahnert et al. (3), and DePauw et al. (9) require further corroboration by future higher-quality randomized investigations.

Overall, the outcomes of higher-quality single-recovery studies (1,13,14,17,27,33,38) indicate that 6–10 minutes of AR intervention conducted postexercise has the potential to promote physiological recovery via decreased muscular BLA concentrations, allowing athletes to maintain or enhance previous levels of athletic performance. Alternatively, the results of other single-recovery studies (2,6,12,13,18,21,25,28) suggest that AR recovery intervals shorter than 6 minutes and longer than 10 minutes negate the physiological benefits of AR that may directly affect improved athletic performance. That being said that there is a lack of research using a recovery window of 3–5 minutes. This may limit the understanding of the effects of AR for interventions of this duration. Despite this limitation, the results of these studies (1,13,17,27,33,38), in addition to the contrasting multiple-recovery studies by Hamlin et al. (15), King et al. (19), Bahnert et al. (3), and DePauw et al. (9), strongly suggest that a 6–10 minutes of AR intervention conducted postexercise may be the ideal time frame to perform AR for facilitating recovery.

Among the studies included, it was evident that no established intensity level for AR interventions currently exists. Eight single-recovery studies of variable quality indicated that the use of heart rate (HR), $\dot{V}O_2$max ($\dot{V}O_2$), maximal aerobic speed (MAS), and MAC may be unreliable markers of prescribing AR intensity levels pertaining to enhancing athletic performance (6,12,13,18,25,28,35). Each of these studies used diverse AR protocols, subject populations, and intervention recovery times; however, each study used HR, $\dot{V}O_2$, MAS, or MAC markers to quantify the intensity level of their administered AR interventions. For example, Jougla et al. (18), Rey et al. (28), and Ouergui et al. (25) used different percentages (50–65%) of the athletes MAC as their marker for AR intensity, whereas Bosak et al. (6) used 65–75% of athletes maximum HR to quantify AR intensity levels. Despite these differences, all 4 authors concluded that AR had either decreased (18) or negligible (6,25,28) effects on subsequent athletic performance.

Two multiple-recovery studies indicated that the use of HR, $\dot{V}O_2$, and MAC may be unreliable to quantify the set intensity levels of AR interventions in regard to athletic performance (19,36). The studies by King and Duffield (19) and Warren et al. (36) used a variety of AR protocols, participant populations, and recovery times, yet, despite contrasting methods, both concluded that AR had no effect on athletic performance while using $\dot{V}O_2$ and HR as markers for AR intensity levels.

King and Duffield (19) not only provided valuable information regarding AR durations but also provided important insight into the lack of reliability of commonly used markers of AR intensity by questioning the underutilization of standardized intensity level markers across numerous levels of athletic competition. They evaluated an AR intervention consisting of low-intensity exercises at an intensity level of 40% of the athlete's $\dot{V}O_2$max. Warren et al. (36) required baseball pitchers to jog at 60% of their maximum HR for 6 minutes between innings eventually tapering to 30% maximum HR by minutes 5–6.

Similar to previous studies (2,6,12,13,18,28,35), both King and Duffield (19) and Warren et al. (36) indicated that AR had no effect on athletic performance despite stark methodological differences. The variability that exists in the percentages and markers used to quantify AR intensity levels add to the lack of supporting evidence regarding the efficacy of AR. There are currently no established guidelines regarding the percentage of AR intensity that should be used by individual athletes. The inconsistency in AR intensity percentages combined with the results of the preceding studies (2,6,12,13,18,19,28,35,36) suggest that the use of MAC, HR, and $\dot{V}O_2$max as markers for AR intensity may need to be reexamined by future high-quality investigations to determine their true effectiveness in quantifying AR intensity levels in relation to athletic performance.

Evidence from 3 single-recovery studies suggest that AR interventions, such as jogging, or cycling, have a potential psychological effect that increases an athlete's perception of recovery, which may positively influence subsequent athletic performance (12,21,35). These studies also used varying AR protocols, subject populations, and recovery times, along with various performance and recovery markers. Yet again, all 3 research groups concluded that AR resulted in decreased (35) or negligible (12,21) effects on athletic performance. Despite these negative findings, the authors documented that athletes displayed consistent positive responses toward AR interventions stating that they often felt "more rested" (9) and "better prepared" (12) for upcoming exertional bouts after AR intervention as compared with passive recovery (PR) controls (12,21,35).

In agreement with the single-recovery studies (12,21,35), 4 multiple-recovery studies also suggested that AR interventions have a potential psychological effect that increases an athlete's perception of recovery, which may positively influence subsequent athletic performance (3,19,22,36). For example, Bahnert et al. (3), King and Duffield (19), Malone et al. (22), and Warren et al. (36) used a variety of different AR protocols (i.e., CWI, CWT, etc), subject populations, and recovery times combined with numerous markers for fatigue, physiological recovery, performance, and intensity levels. These studies proposed that commonly used postexercise AR recovery tactics potentially improve an athlete's perception of musculoskeletal and physiological recuperation; both of which potentially have a significant positive effect on the subsequent athletic performance of the athlete in question. Despite methodological differences, the consistent conclusions reached by all research groups were that AR postexercise interventions resulted in decreased (3,19) or negligible (22,36) effects on athletic performance. Yet despite this, the authors documented that athletes consistently displayed positive affinity toward AR interventions, specifically immersion techniques. Overall findings of these single and multiple recovery studies (3,12,19,21,22,35,36) suggest that future, higher-quality, randomized, controlled trials should further examine the psychological effects of AR using placebo control groups to better distinguish whether the benefits gained from AR interventions, if any, are truly physiological versus psychological in nature.

Interestingly, the individualization of AR seems to be an important factor to consider. Three single-recovery studies of varying quality levels suggested that the application of AR recovery interventions might need to be individualized to have a greater positive effect on specific athletes or subject populations (e.g., sedentary nonathletic vs. athletic populations) (6,11,35). Varying AR protocols, subject populations, and recovery times, as well asand fatigue, physiological recovery, performance, and intensity markers were used in these 3 studies.

All 3 studies (6,11,35) concluded that AR resulted in decreased (35) or negligible (6,11) effects on athletic performance. However, despite mixed findings, Toubekis et al. (35) rationalized that AR interventions should be individualized because the high aerobic fitness (e.g., high $\dot{V}O_2max$ levels) of well-trained athletes could be a cause for the consistent lack of significant effects of AR on athletic performance. This rationale stems from the fact that aerobic fitness has been related to metabolic recovery and performance restoration during repeated maximal exertional bouts in research conducted by Bogdanis et al. (5) and Tomlin and Wenger (32). Toubekis et al. (35) attributed the lack of evidence linking AR to increased performance on the fact that athletes are physiologically superior to nonathletes, and therefore, sedentary people do not undergo as perceptible of physiological changes. This assumption makes it more difficult for current studies to produce viable results clearly illustrating the efficacy of AR interventions in relation to athletic performance.

Multiple-recovery studies by DePauw et al. (10) and Heyman et al. (16) also examined multiple AR intervention methods, leading to their suggestion that AR recovery interventions could have higher rates of effectiveness if they were conducted on an individual basis. These authors, in addition to their distinct declaration, also suggested that individualized implementation of AR interventions may have a greater effect on varying subject populations (e.g., sedentary nonathletic vs. athletic populations) (10,16,22). These authors, like others, used a variety of AR protocol methods, subject populations, and recovery times, coupled with varied markers for fatigue, physiological recovery, performance, and intensity levels. Despite these variations, the authors of each of the 3 studies concluded that AR had no effect on athletic performance.

Studies by DePauw et al. (10), Heyman et al. (16), and Malone et al. (22) agreed with the findings of Toubekis et al. (35) stating that cardiovascular adaptations of an individual athlete plays a significant role in the ensuing physiological response that is displayed by athletes. These findings again relate to the fact that aerobic fitness is directly related to metabolic recovery and performance restoration during repeated maximal exertional bouts (5,32).

The findings of Toubekis et al. (35), DePauw et al. (10), Heyman et al. (16), and Malone et al. (22) create an interesting point of discussion regarding the maximum physiological threshold available within elite athletes. Considering some of the research in this review (5,10,16,22,32,35), it might be suggested that athletes competing at elite levels of competition are essentially physiologically "maxed out," indicating that these athletes may have little, if any, room for further physiological improvement unlike their less athletic and physiologically developed counterparts. As a result, it is crucial to acknowledge when examining elite athletes using AR interventions that the maintenance of physiological and performance levels combined with a lack of detrimental performance or physiologic results could be considered a positive end result. The potential ability of AR interventions to maintain physiological properties may allow elite athletes to compete at a high level for prolonged amounts of time, thus affecting athletic performance in a positive manner.

Given the large physiological variability that exists between individual athletes, the premise of individualized AR interventions is intriguing. Customizing postexercise AR interventions to the demands of individual athletes could be a necessary step needed to elevate the level of effectiveness and specificity of AR interventions as a recovery technique with the potential to positively affect athletic performance. However, the proposed adaptations to the implementation of AR interventions need to be further evaluated by future randomized controlled studies to justify these modifications.

The results of this review suggest that BLA clearance rate is an unreliable marker of enhanced subsequent performance. Five single-recovery studies of various qualities indicated that several AR interventions significantly reduced BLA levels while yielding no effect on performance (12,25,33,35,37). Contrast to previous findings (9–11) was observed by Watts et al. (37) who used an AR protocol involving 15 male expert rock climbers. After a climbing route, subjects underwent either a 10-minute AR ($n = 8$; recumbent cycling) or PR ($n = 7$; sedentary sitting) intervention, followed by a second climb. The subjects' BLA levels were measured at 4 predetermined intervals (preclimb and postclimb 1, 10, 20, and 30 minutes), showing that AR intervention returned BLA to baseline levels 10 minutes faster than the PR intervention, and interestingly, athletes who underwent the AR intervention experienced reductions in hand grip strength compared with the PR group, although not statistically significant. Despite encouraging results pertaining to reduced BLA levels, the study by Watts et al. (37) along with others (12,25,33,35) provide no indication as to whether AR interventions affect athletic performance in any significant capacity. The consistent result of decreased BLA levels combined with inconclusive results (12,33,35,37) pertaining to AR's effect on performance indicates that AR is effective at clearing out metabolic waste products. However, a significant correlation linking reductions in BLA levels to increased athletic performance was not established.

Four multiple recovery studies also demonstrated that AR interventions helped reduce BLA levels after bouts of exertion (9,10,16,23); however, these studies contradict previously accepted findings (12,20,25,26,33–35,37), demonstrating that AR interventions allowed for prolonged athletic performance (9,10,16,23). Each of these 4 studies used a variety of markers, protocols, and subject populations in relation to the examination of AR interventions. DePauw et al. (9,10), Heyman et al. (16), and Monedero and Donne (23) each concluded that AR interventions significantly reduced BLA levels present after bouts of exertion in highly trained rock climbers and cyclists, respectively. However, during these specific studies (10,16,23), the reduction of BLA levels within the blood stream did not equate to an increase in athletic performance but rather an increase in the time subjects were able to participate in their events.

The contrasting results of both single and multiple recovery studies (1,9,10,12,16,19,25,33,35–37), in conjunction with previously accepted ideas regarding BLA reduction increasing the likelihood of enhanced athletic performance (20,26,34), could indicate that the perception of BLA clearance rates as a viable marker for performance enhancement has been mistakenly perpetuated by previous research. This idea has gained continual support over the past 10 years as numerous researchers, including Barnett (4) and Greenwood et al. (13), have argued that lactate removal may not be a valid criterion for properly assessing recovery, especially when examining elite athletes. Much research involving AR is potentially flawed because of the use of lactate removal as a marker for recovery quality and associated performance (4,13,29,31). Therefore, to properly address the concept of BLA clearance rates, future researchers must identify more reliable and accurate markers to measure performance, fatigue, and physiological recovery variables in randomized control trials.

The findings of this systematic review suggest that high-quality research determining the effectiveness of AR interventions on the athletic performance of professional-, collegiate-, and competitive-level adult athletes is limited. The literature regarding the efficacy of AR interventions on athletic performance is varied in design and intervention and displayed inconsistent results. As a result, the systematic review revealed weak indication as to the efficacy of post-exercise AR; however, the 6–10 minutes of AR period was the only component of AR to have consistent support. There exists a need for future research to determine the efficacy of AR, particularly in the determination of reliable and consistent AR markers for fatigue, physiological recovery, and performance from high-quality research outcomes and the intensity and duration for AR intervention sessions. Additionally, research on the 3–5 minutes of recovery period is needed to verify the 6- to 10-minute AR period as the most effective time frame. Furthermore, to provide evidence as to whether AR must be personalized to facilitate performance enhancement, future research should focus on the utilization of individualized recovery protocols instead of broader, less personalized procedures. Finally, future research must examine the potential psychological effects that AR interventions have on an athlete's recovery to help distinguish if the effects of AR are physiological or psychological in nature.

Practical Applications

Athletic trainers, strength and conditioning professionals, and physiotherapists must attentively use AR interventions. It is imperative for practitioners to be consistent and systematic when implementing AR for their athletes and documenting the outcomes to assist in determining whether athletes are demonstrating the desired outcomes of the AR program. The 6- to 10-minute time frame for AR sessions may be the best to use, based on the current evidence. Practitioners must recognize that the outcomes of AR may change as an athlete reaches higher levels of athletic competition; therefore, practitioners should consider that maintenance, rather than improvement, of physiological and performance parameters after AR interventions are a positive therapeutic outcome.

Acknowledgments

The authors have no financial or equipment disclosures to be made related to this systematic review.

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