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Original Article

Effect of active recovery using individual maximum exercise capacity: a pilot study

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Abstract. [Purpose] The intensity of active recovery (AR) for performance recovery is often determined using breath gas analyzers and other special equipment. However, such procedures are difficult to perform in the field or where facilities are inadequate. Although several AR methods using simple patient-derived information have been proposed, only a few have specifically addressed their immediate effects. The present study aimed to quantify the immediate effects of AR, which was determined using the maximum exercise capacity calculated using a physical fitness test without specialized devices. [Participants and Methods] Thirty-two healthy male participants were equally divided into AR and control groups. Each group performed squat jumps, followed by a recovery intervention of jogging at a set intensity in the AR group or rest in a seated position in the control group. Standing long jumps performed before and after the squat jumps as well as after the intervention were analyzed. [Results] The recovery rate for standing long jumps was significantly higher in the AR group than in the control group. [Conclusion] The results of this pilot study indicate that the implementation of AR based on maximum exercise capacity may enhance performance recovery and requires further validation in larger studies.
Key words: Recovery intervention, Performance, Blood lactate

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INTRODUCTION

In the clinical setting of physical therapy for athletes, approximately 90% of sports injuries involve the lower extremities of the ankle, knee, and thigh, with sprains, strains, contusions, tendon disorders, and fractures accounting for 90%[1)]. The main goal of treatment is a swift return to the field. Athletic performance decreases after continuous high-intensity exercise in daily training and matches, which may leave athletes more susceptible to injury[2–4)]. Athletes generally desire to return to their prior sporting level after suffering an injury, defined as return to performance (RTPf)[5)]. However, RTPf is not always attainable; only 31–68% of athletes reportedly achieve RTPf after surgical treatment of a lower extremity injury, with 66–91% returning to their sport below their desired performance level[6)]. Since a certain rate of injury occurs in normal training and competition, it can be inferred that doing those activities in a state of reduced performance is a factor that increases injury risk. In addition, as injury or fatigue may prevent an athlete from performing at his or her peak level, it is imperative to recover performance fully to train and compete in optimal condition as well as from the viewpoint of injury prevention.

Among several effective and immediate methods of performance recovery proposed to date, active recovery (AR) is an approach used in many sports to promote performance recovery. For instance, AR is currently practiced by 81% of French

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professional soccer teams immediately after a game or on the following day[7]. AR consists of low- to moderate-intensity aerobic full-body exercise to promote performance recovery[7]. Several studies have described improved performance and rapid removal of the energy substrate lactate by maintaining such submaximal activity as AR after high-intensity exercise[8–13]. In a study of a professional soccer team, Nédélec et al.[7] found that aerobic activity between 30% and 60% of VO^2max for at least 15 minutes promoted blood lactate (BLa) removal. Monedero and Donne[9] measured performance before and after a fatigue task in well-trained cyclists and reported that the AR group could maintain their pre-task performance level. Menzies et al.[10] had participants run for 5 minutes at 90% VO^2max and performed AR at 0, 20, 40, 60, 80, and 100% of their lactate threshold (LT) and witnessed that AR at 80–100% of LT (25–63% of VO^2max) was more effective in removing lactic acid. It is believed that AR contributes to performance recovery by promoting increased blood flow and lactate metabolism owing to its exercise-based nature[7, 9, 10]. However, most AR intensity settings are based on maximal oxygen uptake and heart rate (HR) and require special equipment, such as expiratory gas analyzers and HR monitors, to implement[9, 10]. The size and cost of these devices may limit the number of athletes able to benefit from AR.

In a study by Wiewelhove et al.[11], the final Velocity attained by Intermittent Fitness Test (VIFT) of the 30-15 Interval Fitness Test (30-15 IFT) was employed to set the intensity of high-intensity interval training and AR. The results of 4-day post-training AR intervention showed a significantly accelerated decrease in lactate. This method of setting AR intensity with VIFT used the individual's maximal exercise capacity without any special equipment. In addition, it could be easily implemented at a sports facility where sufficient space was available, making it useful in sporting situations. However, while Wiewelhove et al.[11] demonstrated the effects of continuous intensity-set AR using VIFT, they and others did not verify the immediate effects of this approach. The advantage of ascertaining the very short-term effects of AR is that limited rest periods can be maximized during training or games, especially in such intervals as half-time breaks.

The purpose of this pilot study was to clarify the immediate effects of AR set using VIFT on performance recovery after a fatigue task. Establishing this form of AR determined without equipment may increase accessibility to athletes during short rest periods and promote more effective performance recovery.

PARTICIPANTS AND METHODS

Thirty-two healthy young adult male students were included in the study after providing oral and written consent. The exclusion criteria were taking vitamin supplements and the presence of orthopedics or neurological diseases of the lower extremities. This study was approved by the University Medical Ethics Review Committee (no. 5030).

The participants underwent background interviews and a physical examination. Sixteen patients each were randomly assigned into the AR group and control group.

The AR group performed the 30-15 IFT to determine VIFT and establish the intervention loading dose prior to testing. The intervention trial was performed between 2 days and 1 week after the 30-15 IFT.

After warming up, each participant performed squat jumps (SJ) as a fatigue task for 90 seconds, followed next by 4-minute recovery intervention. The recovery intervention in the AR group was jogging at 40% of VIFT speed, while that in the control group was resting in a seated position. Both groups then rested in a chair for 20 minutes. Assessments included standing long jump (SLJ) distance, BLa, HR, and Borg scale. BLa, HR, and Borg scale were measured before SJ (pre-SJ; pre), immediately after SJ (post-SJ; post SJ), immediately after the recovery intervention (post-intervention; post I), and then at 5-minute intervals until 20 minutes after the recovery intervention. SLJ was measured at 3 time points: pre, post SJ, and post I.

The smartphone application 30-15IFT (Myorobie Buchheit) was used to determine VIFT. Measurements were taken during the 30-15 IFT, consisting of a 30-second shuttle run between 2 lines 40 m apart followed by a 15-second rest. The first 30 seconds were performed at 8 km/h, which was then increased by 0.5 km/h at each subsequent stage. The pace was controlled by a beep sounding every 20 m. If the 3 m zone placed in front of the 0, 20, and 40 m points was not reached 3 times in succession before the beep sound, the speed for that stage was considered a failure. The velocity of the stage before the last successful one was set as VIFT.

The fatigue task in this study was SJ, which did not require equipment. SJ are used in sports for performance evaluation, training, and fatigue tasks[12–14]. In the SJ method, squatting was performed with the feet shoulder-width apart, knees flexed at 90 degrees, and trunk and lower legs parallel. Participants were instructed to jump upward as high as possible while swinging their upper limbs upward. The participants jumped to a tone of 46 bpm and continued the task for 90 seconds. To ensure maximum effort, the duration of the exercise was not given in advance, and participants were instructed to continue the exercise until the examiner's signal.

SLJ is often used for performance evaluation[15]. One practice session was performed as pre-measurement, and then 2 measurements each were taken at the pre, post SJ, and post I time points. The maximum value attained was adopted for each test.

BLa was measured using a simple blood lactate device (Lactate ProTM 2, ARKRAY, Inc., Kyoto, Japan), Lactate ProTM 2 sensor (ARKRAY, Inc.), and medical puncturing device (Naturalette Petit, ARKRAY, Inc.) as previously described[16]. Decreases in BLa are used in clinical physical therapy and sports settings[17, 18] as an indicator of performance recovery[9, 18, 19]. Since an efficient decrease in BLa indicates improved metabolism and lactate is a common energy substrate[20, 21], BLa measurements were used in this study to assess performance recovery in conjunction with SLJ[9, 18, 19]. The measurement site was a fingertip in the non-dominant hand. The puncture site was washed by hand, wiped with alcohol cotton, and allowed to dry naturally. Blood was then aspirated into the Lactate ProTM 2 sensor to determine BLa concentration. HR was measured with a Polar M200 device (Polar Electro Japan, Tokyo, Japan).

Participants in the AR group jogged back and forth along a 20 m course for 4 minutes at 40% of their VIFT speed (5.6–8 km/h). Pace was controlled by sounding a timer set for each speed every 20 m.

The Shapiro–Wilk test was used to determine normality. Inter-group comparisons of mean BLa for each measurement time in the AR and control groups were performed with the Kruskal–Wallis test. Repeated measures analysis of variance was employed for intra-group comparisons of mean SLJ, while two-way ANOVA was adopted for inter-group comparisons. Comparisons of SLJ recovery rates and changes in BLa and HR between the groups were made using the t-test. Intra- and inter-group comparisons of Borg scale were carried out with the Friedman test and Kruskal–Wallis test, respectively. Statistical analysis was performed using EZR analysis software[22]. All significance levels were set at $p<0.05$.

RESULTS

Consent was obtained from all 32 healthy male participants, who were recruited from the university student population. No significant differences were observed between the two groups for age, height, of body weight (Table 1). None of the participants met the exclusion criteria, although 2 participants in the control group complained of physical discomfort during the last 20 minutes of restful sitting after the recovery intervention and stopped midway through the trial. Therefore, the SLJ analysis, for which all data could be measured, contained 16 participants in each group, while the BLa, HR, and Borg scale analyses included 16 AR participants and 14 controls.

No significant differences were seen for mean SLJ at any time point between the AR group and the control group (pre: 221 ± 18.4 cm vs. 219 ± 18.7 cm, p=0.78; post SJ: 174 ± 27.1 cm vs. 170 ± 26.3 cm, p=0.65; post I: 214 ± 21.5 cm vs. 203 ± 20.0 cm, p=0.17).

In intra-group comparisons, both the AR and control groups showed a significant decrease in mean SLJ at post SJ compared with pre (both p<0.001) and a significant increase in mean SLJ at post I versus post SJ (both p<0.001). On the other hand, mean SLJ at post I was not significantly different to pre values in the AR group (p=0.19), but was significantly lower in the control group (p<0.001) (Table 2).

The recovery rate in the AR group was significantly higher than in the control group (94.7 ± 24.6% vs. 72.9 ± 23.1%, p=0.02) (Table 3).

Before and after SJ, the increase in BLa in the AR group was not significantly different from that in the control group (10.2 ± 2.43 mmol/L vs. 9.41 ± 2.24 mmol/L, p=0.38). Before and after the recovery intervention, however, the decrease in BLa in the AR group was significantly greater by showing a decreasing trend, whereas the control group exhibited an increasing

Table 1. Participant characteristics (n=32)

	Age (years)	Height (m)	Body weight (kg)
AR group (n=16)	20.8 ± 0.91	1.70 ± 0.06	62.1 ± 5.92
Control group (n=16)	20.8 ± 1.52	1.71 ± 0.04	61.3 ± 6.33

Values are expressed as the mean ± standard deviation.
AR: active recovery.

Table 2. Within-group comparisons of SLJ

	AR group		Control group		
Pre (cm)	221 ± 18.4	a (Pre–Post SJ)	219 ± 18.7	c (Pre–Post SJ)	e (Pre–Post I)
Post SJ	174 ± 27.1	b (Post SJ–Post I)	170 ± 26.3	d (Post SJ–Post I)	
Post I	214 ± 21.5		203 ± 20.0		

Values are expressed as the mean ± standard deviation.
a–e, p<0.001; Repeated analysis of variance was used for testing.
SLJ: standing long jump; AR: active recovery; SJ: squat jumps; post I: post-intervention.

Table 3. Comparison of SLJ recovery rate between groups

	AR group	Control group	Unpaired t-test
SLJ recovery rate (%)	94.7 ± 24.6	72.9 ± 23.1	f

Values are expressed as the mean ± standard deviation.
f, p=0.02; Unpaired t-test was used for comparison between groups.
SLJ: standing long jump; AR: active recovery.

trend (−0.92 ± 2.50 mmol/L vs. 1.74 ± 2.15 mmol/L, p=0.004). Afterwards, there was no significant difference in BLa change between the groups during the 20 minutes of chair sitting (−5.41 ± 2.31 mmol/L vs. −5.41 ± 1.71 mmol/L, p=1.00) (Table 4).

The increase in HR in the AR group between before and after SJ was not significantly different from that in the control group (57.4 ± 19.2 bpm vs. 70.1 ± 20.7 bpm, p=0.10). Before and after the recovery intervention, the fall in HR in the AR group was significantly smaller, with an increasing trend in the AR group and a decreasing trend in the control group (10.6 ± 25.4 bpm vs. −34.1 ± 24.3 bpm, p<0.001). During the 20 minutes of chair sitting after the recovery intervention, the decrease in HR during the first 5 minutes was significantly greater in the AR group (−42.1 ± 17.6 bpm vs. −7.00 ± 9.38 bpm, p<0.001), after which no significant difference was seen (−7.50 ± 8.03 bpm vs. −9.35 ± 7.23 bpm, p=0.51) (Table 5).

Borg scale values were not significantly different between the groups at any time point (pre: p=1.00; post SJ: p=0.76; post I: p=0.05; 5 min: p=0.85; 10 min: p=0.82; 15 min: p=0.93; 20 min: p=0.78).

DISCUSSION

This pilot study examined the immediate effects of AR established using VIFT values obtained from 30-15 IFT and without any specialized equipment. Our findings suggested that performance in a fatigue test could significantly more quickly return to pre levels through recovery intervention using AR than that the controls.

Regarding the validity of AR in this study, previous reports described that AR was effective at 67–100% of LT and 25–63% of maximal oxygen uptake[10]. As VIFT and maximal oxygen uptake are correlated, earlier 30-15 IFT studies have presented estimation formulas to calculate maximal oxygen uptake from VIFT values[23, 24]. With VIFT of everyone was calculated based on an estimation equation in the current investigation, the 40% VIFT, the intensity of AR used was 47–53% of maximal oxygen uptake. Thus, the intensity of AR in our cohort was consistent with previous validated studies[10]. Our results were also congruent with the literature in that performance was significantly recovered after AR over controls, with significant reductions in BLa[9, 10]. Since no significant difference in Borg scale findings was seen between the AR and control groups, active exercise might be recommended since the perceived intensity of exercise remained the same. Accordingly, the AR intensity set from VIFT in this study was deemed reasonable and useful.

The AR group had a higher SLJ recovery rate than did the control group and was considered to have recovered significantly faster. Although the mechanism of performance recovery by AR remains unclear, it has been suggested that the increase in blood flow caused by AR promotes lactate metabolism[7, 9, 10]. We observed the AR group showed significantly higher HR during the recovery intervention compared to the control group. Previous studies also reporting higher HR values during AR than in controls indicated that cardiac output and blood flow in the lower extremities were greater during AR[9, 25], indicating that lactate in the blood could be transferred to metabolic tissues by increased blood flow. Indeed, the decrease in BLa in the AR group was significantly greater than in the control group. Earlier reports described that lactate metabolism was enhanced by maintaining submaximal activity, such as AR, after high-intensity exercise, which was consistent with our findings[9, 10, 26]. Lactate is known as an important energy substrate, and its oxidation to pyruvate plays a prominent role in energy production for performance[12, 13]. The observed decrease in BLa implied efficient utilization of energy substrates and was considered as a possible reason for the enhanced performance recovery in this study.

Table 4. Comparisons of amount of change in BLa between groups

	AR group	Control group	Kruskal–Wallis test
SJ–pre (mmol/L)	10.2 ± 2.43	9.41 ± 2.24	
Post I–post SJ (mmol/L)	−0.92 ± 2.50	1.74 ± 2.15	g
20 minutes–post I (mmol/L)	−5.41 ± 2.31	−5.41 ± 1.71	

Values are expressed as the mean ± standard deviation.
g, p=0.004; Kruskal–Wallis test was used for comparison between groups.
BLa: blood lactate; AR: active recovery; SJ: squat jumps; post I: post-intervention.

Table 5. Comparison of HR between groups

	AR group	Control group	Unpaired t-test
Post SJ–pre (bpm)	57.4 ± 19.2	70.1 ± 20.7	
Post I–post SJ (bpm)	10.6 ± 25.4	−34.1 ± 24.3	h
5 minutes–post I (bpm)	−42.1 ± 17.6	−7.00 ± 9.38	i
20 minutes–5 minutes (bpm)	−7.50 ± 8.03	−9.35 ± 7.23	

Values are expressed as the mean ± standard deviation.
h,i p<0.001; Unpaired t-test was used for comparison between groups.
HR: heart rate; AR: active recovery; SJ: squat jumps; post I: post-intervention.

Concerning the immediate effects of AR, all protocols in the present investigation lasted approximately 45 minutes. The higher SLJ recovery rate in the AR group and the significant decrease in BLa during the recovery intervention were in agreement with previous studies that also assessed a protocol of roughly 1 hour[7, 9, 10] and demonstrated an immediate effect of AR with VIFT. Regarding AR duration, a review by Nédélec et al.[7] recommended at least 15 minutes, and similar protocols by Modenero and Donne[9] and Menzies et al.[10] showed effective results after 15 minutes and 40 minutes of AR, respectively. The very short duration of 4 minutes of AR in this study also exhibited effectiveness, indicating that this period was sufficient for the performance assessment and exercise tasks conducted.

The main limitation of this study was that the precise time required to consider each participant's exercise capacity to maximize the effects of AR was not considered. Previous studies have called for differences in the time required for performance recovery in individualized AR intensity[27], whereas our trial standardized AR among participants with respect to time. Moreover, since metabolic changes during the menstrual cycle may affect BLa[28], women were excluded, and so additional studies in larger test groups are warranted to ensure gender-wide applicability.

In conclusion, this study demonstrated an immediate effectiveness of AR determined by VIFT. AR may enable quicker recovery of performance during high-intensity exercise and possibly help prevent injury. Since AR calculation in this study was made with simple equipment, it may be adopted in the clinical setting and in a wide range of sports, regardless of the level of competition, to promote performance recovery even during very short rest periods.

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Conflict of interest

None.

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