Short-Term Heart Rate Recovery is Related to Aerobic Fitness in Elite Intermittent Sport Athletes

Andrew M. Watson,[1,2] Stacey L. Brickson,[2] Evan R. Prawda,[3] and Jenifer L. Sanfilippo[4]

Departments of [1]Pediatrics; and [2]Orthopedics, University of Wisconsin Hospital and Clinics, Madison, Wisconsin; Departments of [3]Kinesiology; and [4]Athletics, University of Wisconsin, Madison, Wisconsin

Abstract

Watson, AM, Brickson, SL, Prawda, ER, and Sanfilippo, JL. Short-term heart rate recovery is related to aerobic fitness in elite intermittent sport athletes. *J Strength Cond Res* 31(4): 1055–1061, 2017—Although heart rate recovery (HRR) has been suggested as a measure of fitness, minimal data exist among athletes. The purpose of this study was to determine if HRR is related to aerobic fitness in elite athletes and whether this relationship is influenced by sex or body composition. Eighty-four collegiate athletes (45 male athletes) underwent body fat percentage (BF%) determination by dual-energy x-ray absorptiometry and maximal treadmill testing followed by 5 minutes of recovery. $\dot{V}O_2$max and heart rate (HRmax) were determined, and HRR was calculated as a percentage of HRmax at 10 seconds, 30 seconds, and 1, 2, 3, 4, and 5 minutes after test completion. After stratifying by sex, participants were grouped as high fit or low fit based on $\dot{V}O_2$max median split. Heart rate recovery was compared between sexes and fitness level at each time point. Multivariable regression analysis was used to identify independent predictors of HRR using $\dot{V}O_2$max, BF%, and sex as covariates. Heart rate recovery did not differ significantly between sexes and was faster among high-fit participants at 10 and 30 seconds, but at no other time. $\dot{V}O_2$max was significantly correlated with HRR at 10 and 30 seconds ($r = -0.34$, $p < 0.001$ and $r = -0.28$, $p = 0.008$) only. After controlling for BF% and sex, $\dot{V}O_2$max remained significantly associated with HRR at 10 seconds ($p = 0.007$) but not at 30 seconds ($p = 0.067$) or any time thereafter. Aerobic capacity is related to faster HRR during the first 30 seconds only, suggesting that only very short term HRR should be used as a measure of aerobic fitness in intermittent sport athletes.

Key Words $\dot{V}O_2$max, body composition, cardiac autonomic function

Address correspondence to Andrew Watson, awatson@uwhealth.org.

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Introduction

Heart rate recovery (HRR) after strenuous exercise has been shown to be faster (i.e., heart rate decreases more quickly) among individuals with higher levels of fitness and after aerobic training programs in a variety of adult and pediatric populations (13,24,30,33). Thought to represent both the restoration of parasympathetic input and the withdrawal of sympathetic tone after exercise, it has been suggested that HRR may therefore be an indicator of changes in fitness level and overall training status (4,15,29). The majority of research conducted regarding the relationship between HRR and aerobic fitness, however, has evaluated either cross-sectional differences between trained and untrained subjects (16,18,19,31) or longitudinal differences among previously sedentary subjects after a period of exercise training (21,22,32). For example, previous research has demonstrated faster HRR among female marathon runners than age-matched, untrained counterparts after maximal exercise, (19), and trained men and women exhibit faster HRR than untrained men and women at absolute, but not relative, submaximal workloads (31). Sugawara (32) found that HRR during the first 30 seconds after submaximal exercise increased after a period of training and decreased during a subsequent period of detraining in initially sedentary men.

Although HRR has been suggested as a simple, inexpensive, and noninvasive means of monitoring fitness in competitive athletes (4,7,15), minimal and conflicting data are available regarding the ability of HRR to differentiate fitness levels within this population (5,11,25). For example, although HRR was not able to discriminate between highly trained endurance athletes with higher or lower levels of fitness (5), an interventional study of well-trained cyclists found a correlation between faster HRR and improved 40-km race time after a 4-week period of high-intensity training (25). In a study of adolescent soccer players, on the other hand, HRR at 1 minute after exercise did not change after a 3-week training intervention (9). Together, these findings suggest that the relationship between aerobic fitness and HRR among athletes is yet to be fully defined.

It has also been suggested that differences in HRR may be influenced by training modality (10,27). Intermittent-sport athletes have been found to have faster HRR than continuous-sport athletes during the first 20 seconds after maximal exercise (27), and high-intensity interval training has been found to elicit a faster HRR than repeated-sprint training in youth soccer players (10). Whereas most research regarding the relationship between HRR and aerobic fitness has been conducted with endurance athletes, less information exists regarding differences in the ability of HRR to detect fitness changes in intermittent athletes. A single study of youth soccer players (11) found a small to moderate relationship between HRR and repeated-sprint performance, but not aerobic fitness. In another study of soccer players, athletes with higher $\dot{V}O_2max$ were found to have faster HRR at 10 and 20 seconds of recovery, but no differences were noted thereafter (28). In light of these results, it remains unclear whether changes in HRR are sufficiently sensitive to identify meaningful changes in aerobic fitness among athletes, particularly in intermittent sports.

It has also been suggested that HRR may be influenced by body composition (12,20) and sex (14,17,26). In a study of 14 professional male cyclists, faster HRR after a 30-seconds supramaximal test was associated with lower body fat, but was unrelated to $\dot{V}O_2max$. In a study of adult men, both body fat and $\dot{V}O_2max$ were found to be significantly associated with HRR, but after inclusion in a multivariable model, only body fat persisted as an independent predictor (20). In 2 previous longitudinal studies of cardiac disease risk, female sex was associated with slower HRR (14,17), whereas a study of young healthy children found that females had slower HRR at absolute, but not relative, submaximal workloads. We are aware of no research, however, which has specifically evaluated sex differences in HRR among competitive athletes. Defining the relationships between aerobic fitness, HRR, sex, and body composition can potentially improve the use of HRR as a monitoring tool for athletes. Therefore, the purpose of this study was to determine the relationship between HRR and aerobic fitness among competitive athletes and determine whether this relationship is influenced by sex or body composition.

METHODS

Experimental Approach to the Problem

The study was a cross-sectional evaluation of the relationships between preseason aerobic fitness, body composition, and HRR in male and female collegiate soccer and hockey players. Immediately before the start of their respective competitive seasons, participants underwent determination of aerobic fitness, body composition, and HRR after maximal exercise.

Subjects

Eighty-four National Collegiate Athletic Association (NCAA) Division I hockey and soccer athletes (ages 18–23 years) participated in this study. All athletes involved with these teams completed the preseason body composition and fitness testing unless they had an injury that precluded them from being able to complete maximal treadmill testing. Individuals were excluded from analysis if they took any medications that could exert an influence on autonomic function (e.g., stimulants). Because the data collected were part of the routine preseason testing for each sport as outlined within the athletic department, separate informed consent was not deemed necessary for retrospective analysis. Nonetheless, this research has been approved by the Internal Review Board of the University of Wisconsin-Madison. Participants were deemed elite given their participation in NCAA Division I teams within one of the most competitive conferences for their respective sports in the country. This represents a highly skilled and very small subset of the population of athletes in their sports, with many players also competing on an international level for their national teams.

Procedures

Immediately before the start of their respective seasons, weight, lean body mass (LBM), and body fat percentage (BF%) were determined for each participant by dual-energy x-ray absorptiometry (DXA) using the Lunar iDXA whole-body densitometer (General Electric, Fairfield, CT, USA). All female participants had a documented negative urine pregnancy test before DXA measurement (MooreBrand, Farmington, CT, USA). Height was determined by a stadiometer to the nearest 0.5 cm. Athletes were encouraged to avoid vigorous physical activity for the 24 hours before fitness testing and to avoid eating or consuming caffeine within 2 hours of the test. On the day of testing, the athletes were familiarized with the equipment and the testing procedure itself. A chest-strap heart rate monitor (Firstbeat, Jyvaskyla, Finland) was placed on the athlete and worn throughout the testing session. The athlete was asked to perform a progressive, maximal treadmill test to volitional exhaustion using a modified Bruce Protocol (6), consisting of 3-minute stages of increasing treadmill speed and incline. Specifically, after the treadmill incline reached 15 degrees, the incline remained constant and the speed was increased 1 mile per hour every 3 minutes until the termination of the test. The test was terminated when the athlete indicated that he/she could no longer continue despite strong verbal encouragement, after which speed and incline of the treadmill were immediately reduced back to 1.7 mph and 0%, respectively, and the athlete was monitored during a 5-minute recovery period of slow walking.

During the test, volumes of oxygen consumption ($\dot{V}O_2$), and carbon dioxide exhalation ($\dot{V}CO_2$) were measured, and respiratory exchange ratio (RER; $\dot{V}CO_2/\dot{V}O_2$) was calculated,

Table 1. Differences in demographic, aerobic fitness, and body composition variables by sport and sex.*

	Total ($n = 84$)	High fit ($n = 42$)	Low fit ($n = 42$)	Males ($n = 45$)	Females ($n = 39$)	Soccer ($n = 41$)	Hockey ($n = 43$)
Age (y)	20.4 (1.4)	20.3 (1.3)	20.6 (1.6)	20.6 (1.6)	20.3 (1.3)	20.2 (1.3)	20.7 (1.5)
Male (% of group)	45 (54)	22 (52)	23 (55)			23 (56)	22 (51)
Height (cm)	174.5 (9.6)	172.6 (8.8)	176.3 (10.2)	179.5 (9.2)	168.6 (6.1)†	175.0 (8.5)	174.0 (10.6)
Weight (kg)	74.8 (9.6)	70.5 (7.0)	78.9 (10.1)†	80.1 (8.7)	68.6 (6.3)†	72.1 (7.3)	77.4 (10.8)†
Body mass index	24.6 (2.6)	23.7 (1.6)	25.4 (3.0)†	24.9 (3.1)	24.1 (1.6)†	23.5 (1.6)	25.5 (2.9)†
Lean body mass (kg)	57.0 (9.6)	54.1 (7.5)	59.7 (10.7)†	64.3 (6.5)	48.6 (4.4)†	55.1 (8.2)	58.8 (10.6)
Body fat percentage (%)	19.7 (6.2)	18.8 (5.8)	20.6 (6.5)	14.9 (2.9)	25.3 (3.8)†	19.1 (6.3)	20.2 (6.1)
$\dot{V}O_2max$ ($ml\cdot kg^{-1}\cdot min^{-1}$)	57.6 (7.4)	61.8 (6.5)	53.4 (5.8)†	62.1 (5.8)	52.3 (5.4)†	59.9 (7.9)	55.4 (6.3)†
Time to exhaustion (min)	16.4 (2.2)	17.1 (2.0)	15.7 (2.3)†	17.9 (1.4)	14.6 (1.6)†	16.5 (2.3)	16.2 (2.2)
Oxygen consumption at ventilatory threshold ($ml\cdot kg^{-1}$ min^{-1})	37.2 (6.0)	44.8 (7.2)	38.0 (5.4)†	44.7 (6.2)	41.3 (7.1)†	42.7 (6.7)	39.9 (7.4)†
Time to ventilatory threshold (min)	10.2 (1.8)	10.8 (2.0)	9.7 (1.4)†	11.2 (1.6)	9.1 (1.3)†	10.2 (1.8)	10.2 (1.8)

*Data presented as mean (*SD*) or n (%).
†$p \leq 0.05$.

in a continuous, breath-by-breath manner by a metabolic cart (Medgraphics, St. Paul, MN, USA). $\dot{V}O_2max$ was considered the highest level of oxygen consumption obtained during the final minute of the test, and time to exhaustion (Tmax) was recorded. Ventilatory threshold (VT) was determined by a single experienced researcher (A.W.) using the V-slope method, defined as the point at which the slope of the increase in $\dot{V}CO_2$ over $\dot{V}O_2$ deflected upward (2), and both oxygen consumption at VT ($\dot{V}O_{2VT}$) and time to VT (T_{VT}) were recorded. A test was considered maximal if the athlete satisfied at least 2 of the following 3 objective criteria: (a) maximal heart rate (HRmax) >90% predicted HRmax; (b) RER ($\dot{V}CO_2/\dot{V}O_2$) > 1.1; and (c) a plateau in oxygen consumption. This plateau was defined as a change of <2 $ml\cdot kg^{-1}\cdot min^{-1}$ in O_2 consumption over the last 60 seconds of the test.

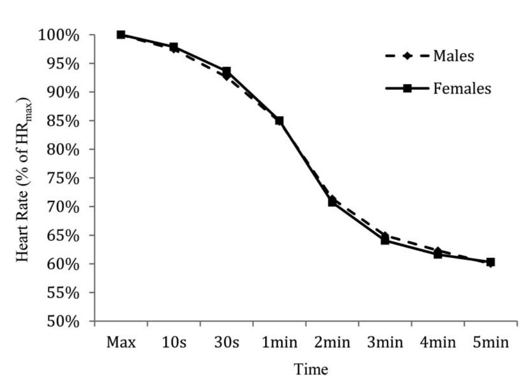

Figure 1. Differences in heart rate recovery as a percentage of maximal heart rate over time between males and females. No significant differences were identified between groups at any single time point.

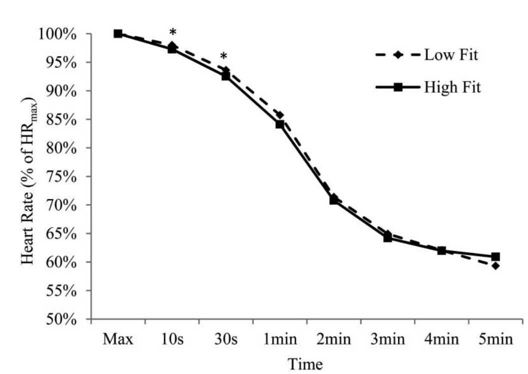

Figure 2. Differences in heart rate recovery as a percentage of maximal heart rate over time between high- and low-fit groups. The high-fit group demonstrated faster heart rate recovery at 10 and 30 seconds, but not at any point thereafter. *$p \leq 0.05$.

TABLE 2. Pearson product-moment correlation coefficients between aerobic fitness and body composition variables and heart rate recovery.*

	HRR_{10s}	HRR_{30s}	HRR_{1min}	HRR_{2min}	HRR_{3min}	HRR_{4min}	HRR_{5min}
Lean body mass	0.00	−0.07	0.01	0.01	0.05	0.03	−0.06
Body fat percentage (%)	0.19	0.23†	0.07	0.05	0.02	0.03	0.008
$\dot{V}O_2max$	−0.34†	−0.28†	−0.02	−0.02	0.04	0.07	0.096
Oxygen consumption at ventilatory threshold	−0.25†	−0.25†	−0.05	−0.14	−0.14	−0.11	−0.007
Time to exhaustion	−0.21†	−0.23†	−0.04	0.06	0.10	0.10	−0.107
Time to ventilatory threshold	−0.21†	−0.29†	−0.22†	−0.20	−0.16	−0.16	−0.055

*HRR is expressed as a percentage of maximal heart rate, such that a lower number indicates a faster heart rate recovery. Therefore, a positive correlation indicates that an increase in the variable is associated with a slower heart rate recovery at that given time point. HRR, heart rate recovery.

†$p \leq 0.05$.

Heart rate was measured beat by beat throughout the test and during the 5-minute recovery after test completion. Maximal heart rate was recorded as the highest HR achieved during the test. Heart rate recovery was calculated as a percentage of HRmax at 10 seconds, 30 seconds, and 1, 2, 3, 4, and 5 minutes after test completion.

Statistical Analyses

Data were evaluated for normality using descriptive statistics and histogram analysis. Data were then grouped by sex (male, female), sport (soccer, hockey), and fitness level using a $\dot{V}O_2max$ median split after stratification by sex (high fit, low fit). Age, height, weight, body mass index, aerobic fitness variables ($\dot{V}O_2max$, Tmax, $\dot{V}O_{2VT}$, T_{VT}), body composition variables (LBM, BF%), and HRR at each time point were compared between groups using independent *t*-tests with an adjustment for multiple pairwise comparisons. (23) Pearson product-moment correlations between aerobic fitness and body composition measures ($\dot{V}O_2max$, $\dot{V}O_{2VT}$, Tmax, T_{VT}, LBM, and BF%) and HRR at each time point were developed for the entire group. A multivariable linear regression was developed to determine independent predictors of HRR at each time point, using sex, $\dot{V}O_2max$, and BF% as covariates. Significance level was determined a priori at the 0.05 level, and all tests were 2-tailed. All statistical analyses were performed using R (Vienna, Austria).

RESULTS

All 84 athletes satisfied the criteria for a maximal test, of which 100% obtained a HRmax greater than 90% of their age-predicted HRmax, 79% obtained an RERmax >1.1, and 54% demonstrated a plateau in $\dot{V}O_2$ at the end of the test. The number of athletes from each sport and sex and the differences in aerobic fitness and body composition variables by fitness level, sex, and sport are shown in Table 1. No differences in HRR were identified between sexes at any time point (Figure 1). The high-fit group was found to have

TABLE 3. Multivariable linear regression to predict HRR at separate time points using $\dot{V}O_2max$, BF%, and gender as covariates.*

	HRR_{10s}		HRR_{30s}		HRR_{1min}		HRR_{2min}		HRR_{3min}		HRR_{4min}		HRR_{5min}	
Variable	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
$\dot{V}O_2max$	−0.10	0.006	−0.10	0.085	0.020	0.87	0.028	0.84	0.025	0.83	0.074	0.50	0.061	0.57
BF%	0.012	0.83	0.023	0.80	0.19	0.34	0.31	0.16	0.25	0.22	0.26	0.16	0.29	0.10
Gender†	0.53	0.41	0.097	0.93	1.51	0.52	3.4	0.19	3.12	0.19	2.5	0.24	3.40	0.11

*HRR at each time point is expressed as a percentage of maximal heart rate, such that a lower number indicates a faster heart rate recovery. Therefore, a positive association indicates that an increase in the variable is associated with a slower heart rate recovery at that given time point. HRR, heart rate recovery; BF%, body fat percentage.

†Gender is treated as a factor such that male = 1, female = 0. Therefore, a positive association suggests that male gender is associated with a slower heart rate recovery.

faster HRR relative to HRmax than the low-fit group at 10 seconds (97.3 vs. 98.0%, $p = 0.041$) and 30 seconds (92.4 vs. 93.6%, $p = 0.049$), but not at any point thereafter (Figure 2). Correlations between HRR and aerobic fitness and body composition variables at each time point are shown in Table 2. Multivariable linear regression analysis found that after controlling for BF% and sex, $\dot{V}O_2max$ remained a significant predictor of HRR_{10s} but not at any point thereafter (Table 3). Body fat percentage and sex were not significantly correlated with HRR at any time point after inclusion in the multivariate model (Table 3).

Discussion

The primary finding of this study is that in elite intermittent sport athletes, HRR is only related to aerobic fitness during the first 30 seconds of recovery, but not at any time point thereafter. Individuals with higher levels of fitness ($\dot{V}O_2max$) exhibited faster HRR during the first 10 and 30 seconds of recovery, but no differences between the groups were identified thereafter. Similarly, in the univariate analysis, $\dot{V}O_2max$, $\dot{V}O_{2VT}$, Tmax, and T_{VT} were all significantly related to HRR_{10s} and HRR_{30s}, but not to HRR at any later time. These results seem to contradict previous studies that have demonstrated relationships between 1-minute HRR and aerobic fitness (21,22,31–33), although it should be noted that these studies have either compared trained and untrained participants or evaluated changes in HRR after an exercise intervention among previously sedentary adults. Differences in HRR between athletes, or in-season changes in HRR among individual athletes, may be relatively small compared with those between trained and untrained individuals, potentially making it more difficult to discriminate between levels of fitness by monitoring HRR.

Research regarding the relationship between HRR and fitness among athletes, on the other hand, is minimal and conflicting. In a recent review that suggested HRR is indicative of training status in athletes (15), 4 of the 5 cross-sectional studies cited examined untrained controls with differences in $\dot{V}O_2peak$ of up to 20 $ml \cdot kg^{-1} \cdot min^{-1}$ from their trained counterparts (16). The single cross-sectional study comparing 2 groups of athletes matched for $\dot{V}O_2max$ but with different VTs found no difference in HRR at 1 minute between the groups. (5) Of the longitudinal studies included, 3 studies investigated HRR at 1 minute in athletes, with seemingly divergent results (3,9,25). One study found faster HRR after training, (25) one found a slower HRR with increased training load (4), and another found no change in HRR with training (9). Finally, an additional cross-sectional study of professional cyclists not included in the review similarly found no relationship between HRR and $\dot{V}O_2max$ (12). Notably, all these studies evaluated HRR recovery at 1 minute, and our present findings are in agreement with those that failed to identify a relationship between aerobic fitness and HRR at this time point. In addition, we found no significant association between HRR and $\dot{V}O_2max$ at any time after 1 minute, suggesting that HRR over this timeframe may not be useful as a surrogate measure of aerobic fitness in athletes.

On the other hand, our findings suggest that aerobic capacity may be related to HRR in athletes during the first 30 seconds after the cessation of exercise. This is in agreement with previous research which found that young male soccer players with higher $\dot{V}O_2max$ values had faster HRR at 10 and 20 seconds, but not at any time thereafter (28). It has also been previously shown that HRR is faster among intermittent-sport athletes compared with their continuous-sport counterparts at 10 and 20 seconds after the termination of exercise, but not thereafter (27). Buchheit (10) compared the relative changes in HRR among adolescent athletes after either repeated-sprint or high-intensity interval training. Although no differences between groups were noted with respect to 1-minute HRR, the interval-training group demonstrated a greater decrease in the 30-second HR time constant. This seems to suggest that different training modalities may elicit differential changes in short-term HRR and that short-term HRR recovery may be particularly important among intermittent sport athletes as an indicator of aerobic fitness.

We also demonstrate that the relationship between short-term HRR and $\dot{V}O_2max$ persists after controlling for the potentially confounding effects of sex and body composition. Although multiple significant inverse relationships were identified between measures of aerobic fitness and HRR_{10s} and HRR_{30s}, $\dot{V}O_2max$ only remained a significant, independent predictor of faster HRR_{10s}, whereas the relationship with HRR_{30s} no longer met the threshold of statistical significance. Esco (20) similarly found no relationship between $\dot{V}O_2max$ and HRR at 1 or 2 minutes postexercise after accounting for the influence of body composition, but did not evaluate HRR within the first minute of recovery. It is possible that intermittent sport athletes are more frequently subjected to high-intensity interval-training modalities, which have been shown to result in both increased $\dot{V}O_2max$ and faster short-term HRR. In practice, this training modality may prioritize recovery of shorter durations than the conventional HRR monitoring period of 1 or 2 minutes, resulting in relatively faster HRR during early recovery periods and a stronger association with aerobic fitness in this population.

The present study is the first that we are aware of that has identified this independent relationship using short-term HRR and has implications for the use of HRR as an indirect measure of aerobic fitness among athletes. With that said, the differences between the fitness groups are relatively small, and interpretation may be difficult in a real-world setting. For example, although statistically significant, the differences in HRR_{10s} and HRR_{30s} are around 1–3 $b \cdot min^{-1}$, making their use to distinguish relative fitness levels between individual high-level athletes difficult. This study is cross-sectional, however, and further research is necessary to determine whether longitudinal changes in short-term HRR in individual athletes can be used to determine changes in aerobic fitness.

This study also found that LBM and BF% were not related to HRR. No significant correlation was identified between LBM and HRR at any time point, and although BF % was correlated with HRR_{30s} in the univariate analysis, it was not significantly associated with HRR at any time point after accounting for $\dot{V}O_2$max and sex in the multivariable model. This is in contrast to a study of moderately active young men, which found an independent relationship between BF% and HRR at 1 and 2 minutes, after controlling for $\dot{V}O_2$max (20). It is possible that these different findings can be explained by differences in methodology, as the studies differed in their estimation of BF% (skinfolds vs. DXA in the present study) and the relative intensity of the postexercise protocol (2.5 mph at 1.5% grade vs. 1.7 mph at 0% grade in the present study). In a more recent study of professional cyclists, Campos (12) found a significant and negative correlation between HRR at 1 minute and BF% and total body fat, but not LBM or $\dot{V}O_2$max. Notably, this study used a 30-second maximal cycling test, whereas our study incorporated a continuous, graded, maximal treadmill test. It has been previously suggested that testing modality can influence postexercise HRR, (8) and it is possible that this effect is at least partly responsible for the differences in the results of that study and ours.

Similarly, we did not identify any sex effect on the relationship between HRR and aerobic fitness. Although males demonstrated higher values in all aerobic fitness variables, HRR was not different between sexes. After inclusion in the multivariable model, sex was not a significant predictor of HRR at any time point. Minimal research exists regarding sex differences in HRR, and the majority of research in athletes has been conducted in males (15). Whereas previous research in healthy adults has found differences in HRR between men and women (17), it has failed to identify any effect of sex on the relationship between fitness and HRR (1). Similarly, a single study of young children found differences in HRR between boys and girls after an equivalent absolute workload, but no relationship between HRR and $\dot{V}O_2$ was identified (26). We are not aware of any previous studies that have previously evaluated the role of sex in HRR among athletes.

This cross-sectional study has limitations. The sample size was based on a convenience sample of collegiate athletes undergoing preseason fitness evaluation and not specifically the result of an a priori power analysis. Although it represents a very light workload, it is possible that the recovery phase of the treadmill test (1.7 mph at 0% incline) could represent a relatively harder or lighter workload for different participants, thereby influencing their relative HRR. It is also possible that other physiologic variables could influence the relationship between aerobic fitness and HRR (e.g., stroke volume, afterload), which were not included in the analysis. There is presently no universally accepted method of determining HRR and methodological differences could partly account for differences between this and previous studies. Nonetheless, we attempted to use a recovery modality (slow, flat walking) that would best approximate the brief recovery conditions during intermittent sports. Finally, our study included only intermittent sport athletes and may not be generalizable to other types of athletes or the general public.

In conclusion, we found that HRR was faster at 10 and 30 seconds among intermittent sport athletes with higher levels of aerobic fitness and that $\dot{V}O_2$max was an independent predictor of faster HRR at 10 seconds, but not at any time thereafter. No significant independent relationships, however, were found to exist between HRR and sex, LBM, or BF% at any time point. These findings suggest that short-term HRR may be a more useful indicator of aerobic fitness among athletes than longer, more traditional monitoring periods.

Practical Applications

As heart rate monitoring becomes increasingly commonplace in athletics, HRR has been used extensively as a simple, noninvasive means of monitoring fitness in athletes. Heart rate recovery has conventionally been measured at 1 or 2 minutes after exercise, but the results of this study suggest that the use of HRR after periodic exercise testing before or during the competitive season as an indirect measure of fitness in intermittent sport athletes should be limited to the first 30 seconds of recovery. The differences in HRR between individuals at these time points are relatively small, however, and the use of HRR alone to compare fitness levels between athletes may be limited.

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