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Effects of Two Different Recovery Postures during High-Intensity Interval Training

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ABSTRACT

The purpose of this study was to examine the effects of two different recovery postures, hands on head (HH) and hands on knees (HK), as a form of immediate recovery from high-intensity interval training (HIIT). Twenty female Division II varsity soccer players (age = 20.3 ± 1.1 yr, body mass index = 22.4 ± 1.80 $\mathrm{kg \cdot m^{-2}}$) completed two experimental trials in a randomized, counterbalanced order. Each trial consisted of four intervals on a motorized treadmill consisting of 4 min of running (4 × 4) at 90%–95% $\mathrm{HR_{max}}$ with 3 min of passive recovery between each interval. HR recovery was collected during the first 60 s of each recovery, where volume of carbon dioxide ($\dot{V}CO_2$) and tidal volume (V_T) were recorded each minute during the 3-min recovery period. Results showed an improved HR recovery ($P < 0.001$), greater V_T ($P = 0.008$), and increased $\dot{V}CO_2$ ($P = 0.049$), with HK (53 ± 10.9 bpm; 1.44 ± 0.2 $\mathrm{L \cdot min^{-1}}$, 1.13 ± 0.2 $\mathrm{L \cdot min^{-1}}$) compared with HH (31 ± 11.3 bpm; 1.34 ± 0.2 $\mathrm{L \cdot min^{-1}}$, 1.03 ± 0.2 $\mathrm{L \cdot min^{-1}}$). These data indicate that HK posture may be more beneficial than the advocated HH posture as a form of immediate recovery from high-intensity interval training.

INTRODUCTION

Athletes of all levels, from novice to elite, are constantly looking for strategies to decrease time to recover and boost athletic performance. It is well known that the respiratory system plays a crucial role during rest and exercise via buffering metabolic by-products, such as hydrogen ions (H^+) and carbon dioxide (CO_2), to maintain the acid–base homeostasis and minimizing dysregulation of the excitation–contraction coupling process in localized muscle tissue (1). Failure to maintain this acid–base homeostasis during exercise can have detrimental effects on performance (2) and often arises when the respiratory system lacks the ability to increase alveolar ventilation, or exercise-induced diaphragmatic fatigue sets (3). Thus, increasing ventilation could subsequently lead to an increase in tidal volume (V_T), a conservation of respiratory rate, and a more efficient work of breathing.

Consequently, researchers have investigated the effects of different postures during recovery from exercise and the physiological responses to these varying recovery postures (4,5,6). Most of the research has focused on evaluating three different positions: supine, seated, and upright, with upright standing posture being the most widely used recovery posture in a sport (field) setting (7). However, new literature has begun to indicate that one can accelerate intermediate recovery between exercise bouts by maximizing the surface area of the diaphragmatic zone of apposition (ZOA) (8); it has been shown that the ZOA is maximized during spinal flexion rather than extension. Because of this, a standing posture with hands on head (HH) may be less advantageous to postures that increase the ZOA (e.g., flexed spine and hands on knees [HK]) (7). The effects of HH versus HK on intermediate recovery and the ZOA have yet to be investigated.

Furthermore, the position of recovery may also influence autonomic function, which could lead to a quicker recovery during performance (9). HR recovery (HRR) has been suggested as a valuable tool in monitoring an athlete's training status and their response to certain training stimuli (10,11,12). A faster HRR has been observed as a result of improvements of aerobic capacity (13). Contrary to this, a delayed HRR results in impaired performance and a greater chance of fatigue (12). Improved HRR in the supine position has been demonstrated following repeated sprint exercise in youth soccer players (14). HR is mediated by parasympathetic reactivation during recovery from exercise. Baroreflex mediation and a prolonged R-R interval in HR that occurs during exhalation is hypothesized to improve the efficiency of gas exchange (15). However, it is unknown if improved HRR during repeated work to rest transitions in exercise influences subsequent performance in trained subjects, especially in female athletes.

Because of the limited information on different standing postures that could directly affect the ZOA and recovery in a

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controlled setting, this study was conducted to determine the effect of using two different recovery postures during standing, HH and HK on various cardiorespiratory functional measures. The study focused on observing minute ventilation ($\dot{V}_E$), carbon dioxide elimination ($\dot{V}CO_2$), and HRR during the recovery intervals of high-intensity interval training (HIIT). $\dot{V}_E$ and frequency of breathing (f_b) were used to calculate V_T. We hypothesized that there would be an effect of the recovery postures, HH and HK, during the recovery period of HIIT on HRR, $\dot{V}CO_2$, and V_T.

METHODS

Experimental Approach to the Problem

In this study, we aimed to determine whether HH and HK recovery postures have a differing influence on recovery of repeated bouts of high-intensity exercise (full description in subsequent sections). The researchers examined how the two different postures could influence cardiorespiratory function during HIIT. The high-intensity interval exercises were performed on a treadmill over an orientation session and two testing sessions where HRR, carbon dioxide elimination ($\dot{V}CO_2$,), and tidal volume (V_T) were determined during the recovery phase of the testing.

Subjects

The study sample consisted of 24 female Division II soccer players between the ages of 18–22 yr old (20.3 ± 1.1 yr). All subjects were in their winter training season when they began participation in the study, had familiarization with HIIT protocol training, and were instructed to not modify their current training routine. Subjects did not partake in any high-intensity activity the day before testing, so that fatigue from previous activity would not affect testing sessions. Subjects refrained from consuming any caffeine the day of testing and obtained a minimal of 7 h of sleep the night before. Uniform verbal encouragement was given to all subjects during all treadmill running sessions. Over the duration of the study, four subjects dropped out. Three subjects dropped out due to time conflicts with their scheduled testing times, and one subject's information was dropped due to incomplete data collection, which resulted in a final subject pool of 20 participants. Table 1 presents subject characteristics and spirometer measures in all 20 subjects. All subjects were informed of protocol, experimental risks, and time involved to complete the study, and they completed an informed consent document before partaking in the investigation. The research project was reviewed and approved by Western Washington University's Human Subjects Committee.

TABLE 1.
Subject Characteristics and Resting Pulmonary Measures.

Subjects	20
Age (yr)	20.3 ± 1.1
Height (m)	1.71 ± 0.10
Body Weight (kg)	65 ± 6.7
BMI ($kg \cdot m^{-2}$)	22.4 ± 1.80
VC (L)	4.0 ± 0.6
FEV_1 (L)	3.1 ± 0.4
FEV_1/VC (%)	80.0 ± 0.1
MVV ($L \cdot min^{-1}$)	133 ± 16

Data are presented as mean ± SD. BMI, body mass index; FEV, forced expired volume; VC, vital capacity; MVV, maximum voluntary ventilation.

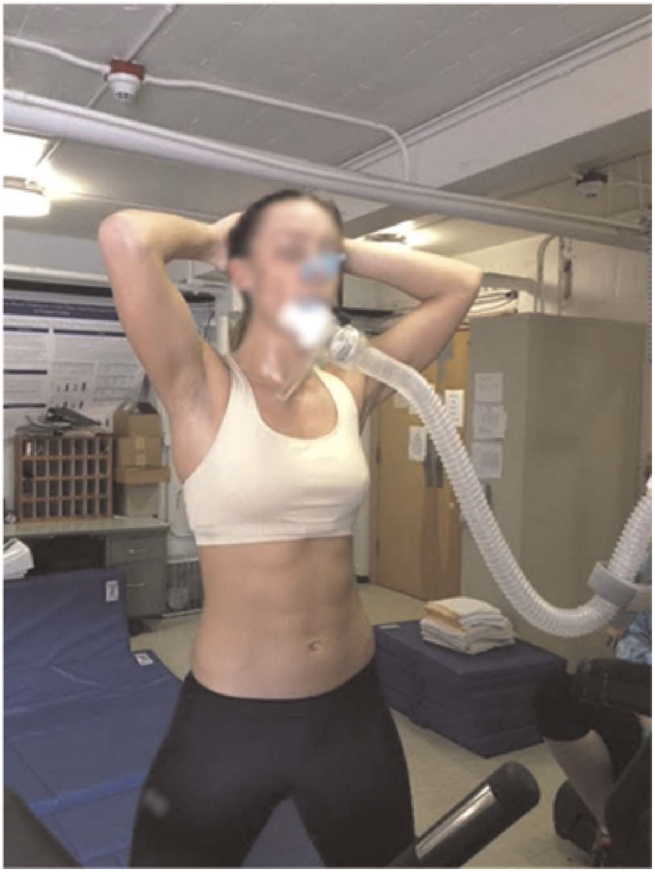


Figure 1: HH recovery posture.

Screening

Each subject completed 1 d of baseline measurements, which included anthropometric measures and pulmonary function tests before testing. The measures were body mass index, vital capacity, forced expired volume in 1 s, forced expired volume in 1 s/vital capacity ratio, and maximum voluntary ventilation. Pulmonary measures were collected using a Parvomedics spirometer. The recovery postures were taught and practiced during the baseline measurement session. HH required them to stand erect with their hands clasped on top of their head (see Fig. 1). HK required them to place their hands on their knees, elbows locked, and flexing through the thoracic region of the spine (see Fig. 2). HK required additional measurement of thoracic flexion with inclinometers (Universal Inclinometers; Lindstrom, Chisago County, MN) to ensure at least 10° of flexion and assure consistency of posture during recovery intervals (6). Two inclinometers were used to measure thoracic flexion at T1 and T12.

Familiarization and Testing

A multiple participant, within-subject design was conducted. Subjects were randomly designated a recovery posture to perform, with the alternate posture for the subsequent testing day. Subjects performed a total of two treadmill sessions of HIIT separated by 1 wk, which consisted of 4 min of running and 3 min of recovery

Figure 2: HK recovery posture.

performed four times (4 × 4 min), assuming one of the two recovery postures during the recovery period. The submaximal runs were performed in the same laboratory on the same motorized treadmill (Precor Treadmill, Woodinville, WA) for each visit. Intensities were set to mimic typical training intensities one experiences in the field, set at 90%–95% of predicted HR_{max} derived from the 220 minus age equation (16). Upon arrival, subjects were fitted with an HR monitor (Polar T31 Transmitter; Polar, Kempele, Finland) and commenced a familiarization session to the subsequent exercise challenges. Subjects returned for a total of two testing sessions, separated by 1 wk. Each session consisted of a 5-min warm-up at a running speed that elicited 70% of their HR_{max} at 0% grade on a treadmill followed by four running intervals at an intensity of 90–95% of HR_{max} for 4 min, with a 3-min passive recovery between runs, assuming either HH or HK postures during recovery. Throughout the 3-min recovery, each subject was fixed with nose clip and a two-way breathing mouthpiece valve interfaced with the metabolic cart (Parvomedics TrueOne Metabolic Cart and Spirometer, Sandy, UT). $\dot{V}CO_2$, $\dot{V}_E$, and f_b were measured every minute over the recovery period. V_T was calculated by dividing $\dot{V}_E$ by f_b. The averages of the respiratory variables during the 3-min recovery were determined and averaged over the four intervals. HRR is commonly defined as the difference in HR at the end of exercise and then 60 s later (17). Similarly, in this study, HRR was measured immediately at the end of the exercise for 1 min.

Statistical Analysis

Descriptive statistics were determined for each variable. Dependent *t*-tests were used to detect significant differences due to the two treatments using the Statistical Package for the Social Sciences for Windows (version 25; SPSS Inc., Chicago, IL). The dependent variables analyzed included HRR, $\dot{V}CO_2$, and V_T during each recovery posture. Significance was defined as a $P \leq 0.05$. Cohen's *d* was calculated for effect size.

RESULTS

Subject characteristics and resting pulmonary measures are presented in Table 1. Comparison of HRR data revealed a significant difference between HH and HK postures. HK posture resulted in significantly faster decrease in HR between intervals than that of the HH posture, 53 ± 10.9 versus 31 ± 11.3 bpm ($P < 0.001$). The effect size was very large, $d = 1.98$. Figure 1 shows the mean and standard deviation of HRR in both postures. A difference of 22 bpm between HK and HH was noted.

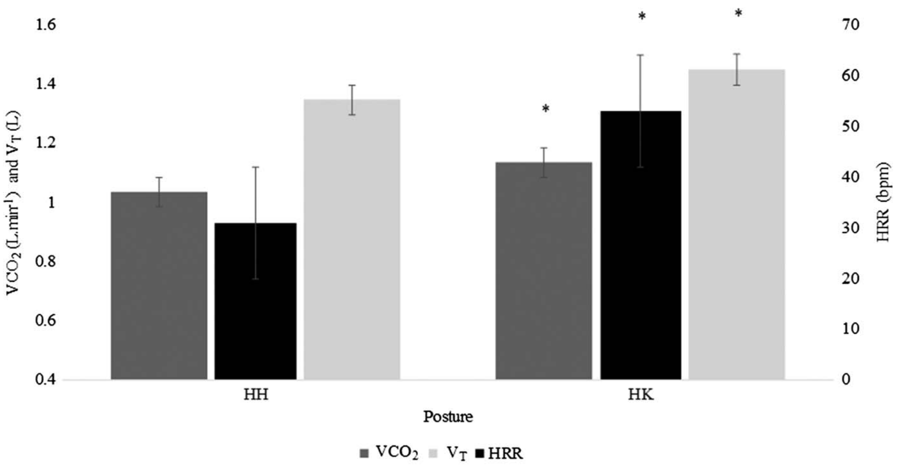
$\dot{V}CO_2$ was averaged over the four recovery intervals to get a mean recovery $\dot{V}CO_2$ for each posture. The statistically significant ($P < 0.05$) effect of the postures was evident between conditions, HK 1.1 ± 0.2 and HH 1.0 ± 0.2 $L \cdot min^{-1}$, respectively (Fig. 2). The effect size was medium, $d = 0.5$. There was a significant difference ($P < 0.05$) between HH and HK postures for V_T. There was a medium effect size, $d = 0.5$. The HK posture significantly increased V_T compared with the HH posture V_T (1.4 ± 0.2 vs 1.3 ± 0.2 $L \cdot min^{-1}$, respectively). Figure 3 reveals the difference in V_T values between the two postures.

HK posture required additional measurement of thoracic flexion with inclinometers (Universal Inclinometers, Lindstrom) during the rest interval to assure consistency of flexion between each rest interval. Averages of thoracic flexion were recorded at each rest interval and were 14.6 ± 4.4°, 15.5 ± 7.0°, 17.6 ± 7.6°, and 19.5 ± 8.2° for rest intervals 1 through 4, respectively.

DISCUSSION

The present study investigated the effects of two different intermediate recovery postures (HH vs HK) on repeated sprint ability in trained female soccer athletes. The results from the investigation show an improved HRR and greater V_T and $\dot{V}CO_2$ with HK posture when compared with HH posture after fatiguing high-intensity intervals. There was substantial improvement in HRR when athletes performed HK (22 bpm improvement) vs HH.

HK posture causes thoracic flexion and internal rotation of the rib cage, which has been reported to optimize the ZOA (18,19). Optimizing the ZOA allows the diaphragm to operate with maximal efficiency (8). This could explain the greater cardiorespiratory response seen in the HK condition, which has been reported in individuals experiencing chronic obstructive pulmonary disease and their reduced feelings of dyspnea (20,21,22). On average, subjects exhibited an increase in thoracic flexion with each rest interval from 14.6 ± 4.4° in the first rest to 19.5 ± 8.2° in the fourth rest interval during HK posture. The increase in thoracic flexion with each rest interval may infer a natural increase in thoracic flexion with fatigue and exercise, further enhancing the ZOA. By contrast, HH posture promotes thoracic extension, which is associated with external rotation of the rib cage and reduced ZOA (8). This mechanical linkage between the diaphragm and ribcage (23) could explain why individuals had a higher HRR after the recovery periods in the HK versus HH postures.



HK = Hands on knees; HH = Hands on head

Figure 3: Mean ± SD of HRR, volume of carbon dioxide ($\dot{V}CO_2$), and tidal volume (V_T) over the four rest intervals in HH and HK postures. Error bars are set at mean ± SD. * Results are significantly different between groups ($P < 0.05$).

Furthermore, HH posture places the diaphragm in a suboptimal position, decreasing its mechanical efficiency. A decrease in the ZOA reduces the ability of the diaphragm to contract effectively because of its poor position along its length–tension curve (10,12). Elevating the arms to 90° or more of shoulder flexion, as observed with HH posture, changes the impedance of the torso, rib cage, and abdominal wall (24,25,26). Raising the arms causes a passive stretch of the thoracic wall and abdominal muscles (overlengthened position), which may place them in a less effective position for assisting in respiration. An overlengthened abdominal region may reduce its ability to effectively oppose the diaphragm, leading to less effective respiratory mechanics (11,18). These muscle length differences could explain the discrepancies observed between HH and HK postures in the current study.

The present study showed increased $\dot{V}CO_2$ values with HK when compared with HH. It is suggested that the HK posture improved exhalation ability of the abdominal muscles, leading to a slight increase in $\dot{V}CO_2$ exhibiting an improved ventilatory profile response. Cavalheri et al. (27) investigated the effects of arm bracing on respiratory muscle strength and pulmonary function in patients with chronic obstructive pulmonary disease. The results showed greater maximal inspiratory and expiratory pressures with arms braced when compared with unbraced arms. The results of the previous study along with the findings of the present study suggest that bracing the arms improves respiratory function by decreasing the postural demands of these muscles, diaphragm, intercostal, abdominals, and accessory muscles during HK.

Kera and Maruyama (21) further supported this idea of improved force generating capabilities with a braced posture. They examined the effects of posture on respiratory activity of the abdominal muscles. The results showed an increased abdominal activity with the braced position (seated, elbows on knees) and was attributed to the enhanced position of the abdominals during trunk flexion. The authors suggested that the abdominals in this position elicited a greater stretch reflex during expiration, thereby increasing inspiration and a reduced feeling of dyspnea in the subjects. Furthermore, diseased populations in previous studies are known to have a low tolerance to arm activities that is not only determined by strength or endurance but by position of the arm itself (28). Arm elevation at 90° shoulder flexion greatly exacerbates respiratory function, altering static ventilatory responses when compared with arms down and below 90° shoulder flexion (28). A study by Couser et al. (24) examined respiratory and ventilatory muscle recruitment with arms elevated and arms down in healthy subjects. They reported an increase in metabolic demand ($\dot{V}O_2$, $\dot{V}CO_2$, and HR) with arms elevated when compared with arms down. These findings were associated with additional increases in $\dot{V}_E$. In contrast to the present study, those subjects were seated and did not perform high-intensity bouts of exercise before measurement of cardiorespiratory variables. The arm positions also differed in both studies and did not follow similar protocols. Our results showed that $\dot{V}_E$ was similar in HH and HK (40.4 and 39.4 L·min^{-1}, respectively). However, V_T was significantly greater with HK (1.4 L·min^{-1}) compared with HH (1.3 L·min^{-1}). Couser et al. (24) attributed the increase in $\dot{V}_E$ with arms elevated to increased V_T and accessory muscle activity, which could explain the discrepancies seen between the studies. Similarly, in the present study, there was a significant increase in V_T with HK in comparison with HH, suggesting an improved work of breathing when adopting HK posture. Subjects also subjectively reported more ease in breathing in the HK posture versus the HH posture. The improvement in HRR with HK posture may be attributed to the improved respiratory mechanics with HK posture, thereby influencing participants' HR.

In addition, posture may have also influenced the interactions between respiration and neurocardiovascular control of recovery from exercise. An autonomic effect may also be influencing the observed accelerated rate of HRR due to the alterations on the parasympathetic reactivation (29). The effect of posture on HRR and parasympathetic reactivation after exercise has been described for supine, sitting, and standing (5,7,9,30). Specific to the present study, improved HRR was demonstrated after repeated sprint exercise after the HK posture. Consistently, supine posture results in accelerated HRR and has been documented in soccer players (14). However, the supine position is not a practical alternative for athletes recovering from repeated sprints in game competition. Thus, the results from this study indicate HK as a viable option when supine positions are not feasible.

CONCLUSIONS AND PRACTICAL APPLICATIONS

The ability to recover faster from multiple bouts of exercise is a crucial part of optimizing performance for athletes in a variety of sports, such as soccer, rugby, basketball, and American football. Thus, using the best recovery modality, in this case posture during HIIT, is crucial to minimize fatigue and potential injuries due to altered biomechanics from the taxing exercise. On the basis of the findings in this study, HK posture significantly improved HRR, V_T, and $\dot{V}CO_2$ in comparison with HH posture. The positive effects of HK posture on HRR, V_T, and $\dot{V}CO_2$ may suggest improved parasympathetic influences and cardiorespiratory mechanics when adopting this posture during a recovery period from a fatiguing exercise.

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