

Respiratory Function and Five-Minute Recovery after Step Exercise in Young Adults with Different Activity Levels

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ABSTRACT

Introduction: Recovery after exercise may give useful information about cardiorespiratory reserve in young adults. This study assessed spirometric recovery after acute step exercise according to habitual physical activity level.

Methods: This analytical cross-sectional study included 168 healthy young adults aged 18–25 years. Participants were divided into low activity, moderate activity and high activity groups based on weekly physical activity. Baseline pulse rate, respiratory rate, oxygen saturation and spirometric parameters were recorded. All participants performed a three-minute step exercise. Immediate post-exercise response and five-minute recovery were assessed. Delayed respiratory recovery was defined as failure of PEFr or FEF25–75 to return to at least 95% of baseline at five minutes.

Results: Baseline FVC was 3.28 ± 0.61 L in the low activity group and 3.59 ± 0.64 L in the high activity group. FEV1 was 2.86 ± 0.47 L and 3.15 ± 0.49 L respectively. PEFr was higher in the high activity group, 7.22 ± 1.38 L/s compared with 6.18 ± 1.46 L/s in the low activity group. Post-exercise heart rate and Borg dyspnoea score were highest in the low activity group. Heart rate recovery >25 beats/min was seen in 29.6% of low activity participants and 78.3% of high activity participants. Delayed respiratory recovery was 48.1% in the low activity group and 15.2% in the high activity group. Low activity independently predicted delayed recovery.

Conclusion: Higher habitual physical activity was associated with better baseline spirometric profile and faster recovery after acute step exercise.

Keywords: Physical activity; Spirometry; Step exercise; Pulmonary function; Heart rate recovery; Young adults.

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Introduction

Spirometry is a simple and useful test for assessment of ventilatory function. Forced vital capacity, forced expiratory volume in one second and peak expiratory flow give practical information about lung volume and airway flow. Standardized performance of spirometry is important because effort, posture and technique can affect the values obtained.[1]

Physical activity is an important modifiable factor for cardiorespiratory health. The World Health Organization recommends regular moderate or vigorous physical activity for adults to improve health and reduce sedentary risk.[2] Exercise training improves cardiovascular efficiency, skeletal muscle oxygen use and autonomic recovery. Its relation with lung function is less direct but clinically relevant.

Previous studies have shown mixed findings on physical activity and spirometric function. Bédard et al. reported a positive relation between physical

activity and lung function, but also highlighted the problem of reverse causation.[3] Svartengren et al. found that physical activity was associated with better FEV1 and FVC independent of obesity in a large adult population.[4] This suggests that activity level may influence respiratory health beyond body mass alone.

Cardiorespiratory fitness may be an important link between physical activity and lung function. Ostolin et al. showed that cardiorespiratory fitness mediated a major part of the association between moderate-to-vigorous physical activity and FVC and FEV1 in adults.[5] Mensink-Bout et al. also reported that lower fitness was associated with lower lung function in adolescents.[6] Collaud et al. found weak but significant association of moderate and vigorous physical activity with FEV1 and FVC in a healthy community-based population.[7] These studies support the need to assess fitness and activity pattern along with spirometry.

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Most simple exercise studies report only pre-exercise and immediate post-exercise spirometric values. This gives limited information. Recovery after exercise may show additional physiological reserve. Heart rate recovery, dyspnoea score and return of flow parameters toward baseline may provide useful field-level indicators of cardiorespiratory adaptation. Thomas et al. noted that heart rate recovery alone may not be a strong single marker of fitness in young sedentary adults, so it should be interpreted with other measures.[8] Acute exercise can produce measurable short-term changes in heart rate, respiratory rate and pulmonary function. Jin et al. assessed cardiorespiratory markers before and after moderate exercise in healthy young adults and showed that acute exercise response can be studied using simple physiological parameters.[9] However, data are still limited regarding how habitual physical activity level affects spirometric recovery after acute step exercise in young adults.

The present study was planned to assess baseline respiratory profile, immediate response and early recovery after acute step exercise among young adults according to physical activity level. The study also aimed to identify simple predictors of delayed respiratory recovery using heart rate recovery, dyspnoea score and selected spirometric parameters.

Materials and Methods

This analytical cross-sectional study was conducted in the Department of Physiology after Institutional Ethics Committee approval. A total of 168 healthy young adults aged 18–25 years were included after written informed consent. Participants with asthma, chronic respiratory disease, cardiac illness, current smoking, recent fever, recent vigorous exercise, or lower limb injury were excluded.

Demographic details, physical activity history, height, weight and BMI were recorded. Based on weekly physical activity, participants were grouped into low, moderate and high activity categories. Resting pulse rate, respiratory rate and oxygen saturation were noted after 10 minutes of rest.

Spirometry was done using a calibrated portable spirometer as per standard recommendations.[1] FVC, FEV1, PEFr, FEV1/FVC ratio, FEF25–75 and MVV were recorded. Each participant then performed a three-minute step exercise on a 30 cm platform at 24 cycles per minute. Pulse rate, respiratory rate, SpO₂ and Borg dyspnoea score were recorded immediately after exercise. Spirometry was repeated within two minutes and again selected recovery parameters were recorded at five minutes. Delayed respiratory recovery was defined as failure of PEFr or FEF25–75 to return to at least 95% of baseline value at five minutes. Data were analysed using SPSS. Continuous variables were expressed as mean \pm SD or median with IQR. Categorical variables were expressed as number and percentage. ANOVA, Kruskal-Wallis test, chi-square test and

logistic regression were used as applicable. A p-value <0.05 was taken as statistically significant.

Results

Table 1: Participant profile according to physical activity level

Variable	Low activity (n=54)	Moderate activity (n=68)	High activity (n=46)	p-value
Age, years	21.6 \pm 2.1	21.2 \pm 2.4	20.9 \pm 2.2	0.218
Male sex	32 (59.3)	39 (57.4)	29 (63.0)	0.842
Body mass index, kg/m ²	22.8 \pm 2.7	22.1 \pm 2.5	21.3 \pm 2.2	0.018
Resting pulse rate, beats/min	82.4 \pm 9.1	78.6 \pm 8.3	72.9 \pm 7.6	0.0004
Weekly physical activity, min/week	42 (20–75)	156 (120–210)	318 (270–420)	0.0002

A total of 168 young adults were included. Low activity group had 54 participants, moderate activity group had 68 participants and high activity group had 46 participants. Age was comparable across the three groups. Mean age was 21.6 \pm 2.1 years in low activity group, 21.2 \pm 2.4 years in moderate activity group and 20.9 \pm 2.2 years in high activity group (p=0.218). Sex distribution was also similar (p=0.842). BMI was lower in the high activity group. It was 22.8 \pm 2.7 kg/m² in low activity group and 21.3 \pm 2.2 kg/m² in high activity group (p=0.018). Resting pulse rate showed a significant decreasing trend with increasing activity level. It was 82.4 \pm 9.1 beats/min in low activity group and 72.9 \pm 7.6 beats/min in high activity group (p=0.0004). Weekly physical activity was significantly different between groups (p=0.0002).

Table 2: Baseline respiratory profile according to physical activity level

Parameter	Low activity (n=54)	Moderate activity (n=68)	High activity (n=46)	p-value
FVC, L	3.28 \pm 0.61	3.43 \pm 0.58	3.59 \pm 0.64	0.031
FEV1, L	2.86 \pm 0.47	3.02 \pm 0.51	3.15 \pm 0.49	0.012
PEFR, L/s	6.18 \pm 1.46	6.74 \pm 1.52	7.22 \pm 1.38	0.004

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FEV1/FVC ratio	0.872 ± 0.064	0.881 ± 0.058	0.879 ± 0.061	0.71 1
MVV, L/min	108.6 ± 21.4	115.9 ± 20.7	126.8 ± 24.1	0.00 2
Resting SpO ₂ , %	98.1 ± 1.1	98.3 ± 1.0	98.5 ± 0.9	0.07 6

Baseline spirometric values were better in the high activity group. FVC was 3.28 ± 0.61 L in low activity group, 3.43 ± 0.58 L in moderate activity group and 3.59 ± 0.64 L in high activity group (p=0.031). FEV1 also increased across activity groups. It was 2.86 ± 0.47 L, 3.02 ± 0.51 L and 3.15 ± 0.49 L respectively (p=0.012). PEFR was 6.18 ± 1.46 L/s in low activity group and 7.22 ± 1.38 L/s in high activity group (p=0.004). MVV was also significantly higher in the high activity group (126.8 ± 24.1 L/min) compared with low activity group (108.6 ± 21.4 L/min) (p=0.002). FEV1/FVC ratio and resting SpO₂ did not show significant difference between groups.

Table 3: Immediate cardiorespiratory response after acute step exercise

Parameter	Low activity (n=54)	Moderate activity (n=68)	High activity (n=46)	p-value
Post-exercise heart rate, beats/min	151.7 ± 15.6	139.4 ± 14.2	127.8 ± 13.5	0.000 2
Post-exercise respiratory rate, breaths/min	31.2 ± 4.5	28.7 ± 4.1	26.4 ± 3.8	0.000 6
Borg dyspnoea score	4.3 ± 1.3	3.4 ± 1.2	2.8 ± 1.0	0.000 3
Fall in SpO ₂ , %	-1.2 ± 1.1	-0.8 ± 0.9	-0.5 ± 0.8	0.021
Immediate change in FEF25–75, L/s	-0.18 ± 0.42	-0.05 ± 0.39	0.08 ± 0.36	0.014
Immediate change in PEFR, L/s	0.42 ± 1.12	0.74 ± 1.18	1.10 ± 1.05	0.009

Immediate post-exercise response differed significantly according to activity level. Post-exercise heart rate was highest in the low activity group and lowest in the high activity group. It was 151.7 ± 15.6 beats/min, 139.4 ± 14.2 beats/min and 127.8 ± 13.5 beats/min respectively (p=0.0002).

Post-exercise respiratory rate showed the same pattern (p=0.0006). Borg dyspnoea score was 4.3 ± 1.3 in low activity group and 2.8 ± 1.0 in high activity group (p=0.0003). Fall in SpO₂ was small in all groups but was more in low activity participants (p=0.021). Immediate change in PEFR was higher in high activity group, 1.10 ± 1.05 L/s compared with 0.42 ± 1.12 L/s in low activity group (p=0.009). Immediate change in FEF25–75 was also significantly different between groups (p=0.014).

Table 4: Five-minute recovery profile after acute step exercise

Recovery parameter	Low activity (n=54)	Moderate activity (n=68)	High activity (n=46)	p-value
Heart rate recovery >25 beats/min	16 (29.6)	35 (51.5)	36 (78.3)	0.000 5
Respiratory rate returned near baseline	22 (40.7)	41 (60.3)	36 (78.3)	0.001 6
PEFR ≥95% of baseline at 5 min	25 (46.3)	44 (64.7)	35 (76.1)	0.010
FEF25–75 ≥95% of baseline at 5 min	21 (38.9)	39 (57.4)	32 (69.6)	0.012
Borg dyspnoea score ≤1 at 5 min	20 (37.0)	38 (55.9)	34 (73.9)	0.002
Delayed respiratory recovery	26 (48.1)	20 (29.4)	7 (15.2)	0.001 2

Five-minute recovery was better in the high activity group. Heart rate recovery >25 beats/min was seen in 16 participants (29.6%) in low activity group, 35 participants (51.5%) in moderate activity group and 36 participants (78.3%) in high activity group (p=0.0005). Respiratory rate returned near baseline in 40.7%, 60.3% and 78.3% respectively (p=0.0016). PEFR recovery to ≥95% of baseline was seen in 46.3% of low activity group and 76.1% of high activity group (p=0.010). FEF25–75 recovery to ≥95% of baseline was also better in the high activity group (p=0.012). Borg dyspnoea score ≤1 at five minutes was present in 37.0% of low activity

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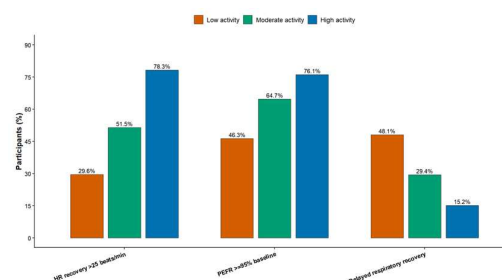
group and 73.9% of high activity group ($p=0.002$). Delayed respiratory recovery was highest in low activity group, 26 participants (48.1%) and lowest in high activity group, 7 participants (15.2%) ($p=0.0012$).

Table 5: Predictors of delayed respiratory recovery after exercise

Variable	Adjusted OR	95% CI	p-value
Low activity level vs high activity	3.84	1.46–10.12	0.006
Moderate activity level vs high activity	2.12	0.83–5.42	0.116
Resting pulse rate per 10 beats/min	1.58	1.10–2.29	0.015
Borg dyspnoea score per 1-point increase	1.39	1.04–1.87	0.027
Baseline MVV per 10 L/min increase	0.82	0.69–0.97	0.024
BMI per 1 kg/m ² increase	1.07	0.94–1.21	0.305

On logistic regression, low activity level was significantly associated with delayed respiratory recovery. Low activity participants had higher odds of delayed recovery compared with high activity participants (adjusted OR 3.84, 95% CI 1.46–10.12; $p=0.006$). Moderate activity showed higher odds but it was not statistically significant (adjusted OR 2.12, 95% CI 0.83–5.42; $p=0.116$). Resting pulse rate was also a significant predictor. Each 10 beats/min increase in resting pulse rate increased the odds of delayed recovery (adjusted OR 1.58, 95% CI 1.10–2.29; $p=0.015$). Higher Borg dyspnoea score was associated with delayed recovery (adjusted OR 1.39, 95% CI 1.04–1.87; $p=0.027$). Higher baseline MVV showed a protective association (adjusted OR 0.82, 95% CI 0.69–0.97; $p=0.024$). BMI was not significantly associated with delayed respiratory recovery.

Figure 1: Recovery response after acute step exercise according to physical activity level



Discussion

The present study showed a clear difference in cardiorespiratory profile according to habitual physical activity level. Age and sex distribution were comparable between the groups. BMI was lower in the high activity group. Resting pulse rate also showed a graded decline from low activity to high activity group. This suggests better basal cardiovascular conditioning in physically active participants.

Baseline spirometry was better in the high activity group. FVC increased from 3.28 ± 0.61 L in the low activity group to 3.59 ± 0.64 L in the high activity group. FEV1 increased from 2.86 ± 0.47 L to 3.15 ± 0.49 L. PEFR was also higher in the high activity group, 7.22 ± 1.38 L/s compared with 6.18 ± 1.46 L/s in the low activity group. MVV showed a similar pattern. This indicates better ventilatory performance in physically active young adults. Okon et al. studied 40 healthy young adults and reported significant improvement in FEV1, FVC and PEFR after 14 days of moderate aerobic exercise.[10] Rajaure et al. studied 131 professional athletes and found that aerobic athletes had significantly higher FEF25–75 by 13.42% and MVV by 8.58%, though FVC and FEV1 were not significantly different.[11] The present findings are in the same direction, mainly for flow parameters and MVV.

Immediate response after exercise also differed between groups. Post-exercise heart rate was highest in the low activity group and lowest in the high activity group. Respiratory rate and Borg dyspnoea score showed the same pattern. Fall in SpO₂ was small in all groups but was more in low activity participants. Immediate PEFR improvement was higher in the high activity group. These findings suggest lower acute physiological stress after exercise in physically active participants. Jin et al. reported that acute exercise in healthy young adults was generally safe in low and medium air pollution environments, but high pollution exposure was associated with decline in FVC, FEV1 and PEF and increase in inflammatory markers.[12] This supports that acute exercise response is influenced by baseline conditioning and surrounding physiological stressors.

Recovery findings were clinically more useful than only pre-post spirometry. Heart rate recovery >25 beats/min was seen in 78.3% of high activity participants, compared with 29.6% of low activity

participants. PEFR recovery to $\geq 95\%$ of baseline at five minutes was also more common in high activity group. Delayed respiratory recovery was 48.1% in the low activity group and only 15.2% in the high activity group. This suggests that habitual physical activity may improve early recovery reserve after submaximal exertion. Facioli et al. studied 60 healthy men divided by cardiorespiratory fitness and found that higher fitness was associated with lower baseline heart rate and faster heart rate recovery after exercise.[13] Thomas et al. reported that heart rate recovery alone was not a valid single marker of cardiorespiratory fitness in young sedentary adults.[14] Hence, the combined use of heart rate recovery, dyspnoea score and spirometric recovery appears more practical.

Delayed respiratory recovery was independently associated with low physical activity level. Low activity participants had nearly four times higher odds of delayed recovery when compared with high activity participants. Higher resting pulse rate and higher Borg dyspnoea score were also associated with delayed recovery. Baseline MVV showed a protective association. BMI was not a significant predictor. This suggests that functional reserve and activity habit may be more important than body size alone in young adults. Wang et al. reported that sedentary behaviour more than 4 hours/day was negatively associated with FEV1 and that moderate-to-vigorous physical activity could reduce this association only when sedentary time was not excessive.[15] This supports the view that both activity and sedentary habit should be considered while interpreting respiratory fitness.

The physiological basis may be related to better respiratory muscle conditioning, more efficient breathing pattern and faster autonomic recovery in active individuals. Exercise training is known to improve functional reserve of respiratory system and respiratory muscle performance.[16] Better diaphragmatic breathing pattern has also been associated with better spirometric and respiratory function values in endurance-trained subjects.[17] Regular physical activity may improve skeletal muscle oxidative capacity and exercise efficiency. This can reduce ventilatory load for a given level of exertion.[18] Heart rate recovery mainly reflects parasympathetic reactivation after exercise. Liu et al. reported that sedentary time and moderate-to-vigorous physical activity were associated with abnormal heart rate recovery in young and middle-aged adults.[19] This can explain the lower post-exercise heart rate, lower dyspnoea score and better five-minute recovery seen in the high activity group. However, this study cannot prove causality. It only shows an association between habitual activity level and acute recovery response.

The study has some limitations. It was a single-centre study with young adults, so findings may not apply to older subjects or patients with respiratory

disease. Physical activity was classified by reported weekly activity and not by accelerometer. Exercise testing was field-based and VO_2 max was not measured. Bronchodilator testing and long-term follow-up were not done. Still, the study gives useful data on simple recovery-based respiratory assessment after acute step exercise.

Overall the physically active young adults showed better baseline spirometric profile, lower immediate cardiorespiratory stress and faster recovery after acute step exercise. Low physical activity, higher resting pulse rate and higher dyspnoea score were associated with delayed respiratory recovery. The findings support the use of simple recovery markers along with spirometry in young adults.

Conclusion

Physically active young adults showed better baseline pulmonary function and lower immediate cardiorespiratory stress after step exercise. Five-minute recovery was also better in the high activity group, with higher heart rate recovery and better return of PEFR and FEF₂₅₋₇₅ toward baseline. Low habitual physical activity was associated with delayed respiratory recovery even after adjustment for other variables. These findings suggest that simple recovery-based assessment may be useful along with spirometry for evaluating functional respiratory reserve in healthy young adults.

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