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# Maximal Step Test: A New Approach to Step Test Improvements

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**Abstract:** The purpose of this study was to introduce a new maximal step test (NMST) with adjusted step height based on the knee joint angle of 90°. Thirty female students of physical education participated in the study and performed both NMST and a maximal graded excise test (GXT) to measure maximal oxygen consumption ($VO_{2max}$). There were significant correlations between $VO_{2max}$, Peak Heart Rate (PHR) and respiratory quotient in both tests ($P \leq 0.01$). NMST as a maximal step test does not require many resources and is also not very expensive. In addition, modification of the step height based on the knee angle of 90° in NMST reduces muscle fatigue or pain and also may lessen the inter individual variability in oxygen cost during the task. Therefore, NMST is recommended as a valid and a simple test to evaluate $VO_{2max}$ with high accuracy.

**Abbreviated:** New maximal step test with adjusted step height based on the knee joint angle of 90°
**Key words:** Maximal Step Test · $VO_{2max}$, Step Height · Knee Angle of 90°

## INTRODUCTION

$VO_{2max}$ is the primary indicator of endurance performance, which can be measured by maximal or sub maximal tests [1]. Direct measurements for $VO_{2max}$ are considered impractical in non-laboratory field conditions due to their requirement for extensive equipment and technical expertise. As a result, many other tests such as step tests have been developed in order to estimate the aerobic capacity [2].

Most commonly step tests are performed at a fixed cadence on a bench of fixed height [3]. A number of researchers have suggested that when conducting a step test, the height of the step should be adjusted to the participant`s stature in order to prevent local muscle fatigue before reaching the true aerobic capacity. They have concluded that this may decrease the inter subject variability in oxygen cost and heart rate during a task and as such, may produce a more valid prediction of $VO_{2max}$ [4,5].

Because stepping efficiency may be affected by the angle of pull of the muscle, step height based on angle of the knee joint may provide more efficient stepping and enhance the validity of the step test in predicting maximal oxygen capacity [1]. Shino (1971) suggested that the most convenient step would produce knee joint angle of approximately 90° [6]. Therefore, the purpose of this study was to introduce a new maximal step test (NMST) with adjusted step height based on the knee joint angle of 90° for the physical education students of Tehran university.

## MATERIALS AND METHODS

**Participants:** Thirty active female students With (Mean ± SD, ages: 23.6±2.11 yr, height: 164.63±7.14cm, weight: 60.97±4.01 kg, body fat percent: 23.6 ± 2.11). volunteered as subjects and randomly chosen from faculty of physical education of Tehran University. all participants were informed of the purpose, procedures and possible risks of the investigation before they gave written informed consent to participate in the study.

**Experimental Design:** $VO_{2max}$ of each participant was determined by both NMST and maximal graded excise test (GXT) on a cycle ergo meter, at an interval of four days. They were instructed to arrive at the laboratory in a rested and a fully hydrate state, also to avoid strenuous exercise 48h preceding the test session.

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**New Maximal Step Test:** The appropriate height for each participant was established by the height of the dominant foot when the knee was fixed at 90°. Step frequency and duration per stage were designed in order to cause exhaustion in 8-12 minutes. Participants began stepping a rate of 14 steps/min , with an increase in cadence of 4 steps/min every two minutes up to the point of fatigue (volitional exhaustion) or when the participant could no longer maintain the stepping rate for 15 seconds. Gas exchange parameters were recorded breath-breath (ZAN680, Spiroergometry system, Germany). Participants self selected the lead leg and could change the lead leg at any time during the test. RPE (Borg 1994) was also obtained every two minute [7]. The test was approved as being maximal when at least four of the following five criteria was met: 1) a plateau in VO2 despite increased work rate (increase by< 150 ml/min) 2) R-value > 1/15 3) ventilatory equivalent for oxygen > 30 4) the participant reported a rating of perceived exertion (RPE) of 19/20 on the Borg scale 5) heart rate reached age-related maximum (220-age) [1].

**Maximal Graded Excise Test:** The GXT session was consisted of a 3 min warm up on a cycle ergometer without any loads. It was followed by a graded protocol starting at 25w and increasing by 25w every 2 minute until volitional exhaustion. Gas exchange parameters were recorded breath-breath (ZAN680, Spiroergometry system, Germany). Resistance was designed to cause exhaustion in 8-14 minutes. The test was approved as being maximal when at least four of the five criteria mentioned in the NMST were met.

**Statistical Analysis:** The data are presented in terms of mean ± standard deviation. Paired t test, Pearson's product moment correlation were used for statistical treatment of data. SPSS version 13 was used to analyses the data. P-value<0.05 was considered statistically significant.

## RESULTS

Results indicated higher values for $VO_{2max}$ and heart rate in NMST compared with GXT. T-test and correlation results between NMST and GTX are shown in table 1 and 2. Also, total time and $VO_{2max}$ assessment time showed no significant differences in the two tests.

## DISCUSSION

Step tests are one of the most widely used tests for estimating aerobic capacity. They are popular because they have several advantages over the ergo metric procedures. For instant, stepping requires neither elaborate or expensive equipment nor, calibration and can be easily administered to large numbers of people [8].

As stepping efficiency may seem to be influenced by the step height [9], it will be difficult to assess $VO_{2max}$ accurately unless the height of the step is adjusted. Accordingly, step tests based on the participant`s stature may lessen the inter individual variability in oxygen cost and heart rate during a task and therefore, may produce amore valid prediction of aerobic capacity [5].

An important determinant in the measurement of $VO_{2max}$ is the quantity of the muscle mass stressed when performing a task or mode of exercise used to elicit maximal oxygen uptake [1]. NMST, same as other step tests, involves large group of muscles with adequate intensity and time to enable the prediction of $VO_{2max}$. Step tests underestimate $VO_{2max}$ by 12-13.5% compared to treadmill taste while, overestimate $VO_{2max}$ by approximately 12% against GXT [1]. However, maximal tests such as NMST are more accurate than sub maximal tests.

Table 1: T-test results between NMST and GTX

| Test | End Heart Rate | RER | RPE | Ventilatory Equivalent | $VO_{2max}$ (ml/kg/min) |
|---|---|---|---|---|---|
| NMST | 195.96±9.08 | 1.14±0.03 | 18.33±2.28 | 36.76±4.16 | 32.18±6.19 |
| GXT | 184.63±8.30 | 1.28±0.12 | 18.56±1.54 | 36.83±3.53 | 29.39±5.12 |
| t | 5.04 | -5.9 | -0.4 | -0.06 | 2.5 |
| P | 0.001* | 0.001* | 0.65 | 0.94 | 0.01* |

*P<0.05

Table 2: Correlation between NMST and GTX

| Test | End Heart Rate | RER | RPE | Ventilatory Equivalent | $V_{O2max}$(ml/kg/min) |
|---|---|---|---|---|---|
| NMST | 195.96±9.08 | 1.14±0.03 | 18.33±2.28 | 36.76±4.16 | 32.18±6.19 |
| GXT | 184.63±8.30 | 1.28±0.12 | 18.56±1.54 | 36.83±3.53 | 29.39±5.12 |
| r | 0.82 | 0.19 | 0.14 | 0.49 | 0.73 |
| P | 0.001* | 0.29 | 0.44 | 0.005* | 0.001* |

*P<0.05

Nevertheless, maximal tests include some disadvantages such as requiring participants to go to volitional maximum, considerable requirement of time, personnel and resources and the limitation of test performance by local muscle fatigue or pain rather than cardio respiratory insufficiency [3,1]. But on the other hand, NMST does not require many resources and is also not very expensive.

In addition, modification of the step height based on the knee angle of 90° in NMST reduces muscle fatigue or pain. Ashley *et al.* (1997) concluded that during maximal step tests it seems that participants were not giving a maximal effort due to their low heart rate, RPE and respiratory quotation [9] while, in the NMST participants assessed 100% of the heart rate.

Moreover, because there is a specific rhythm when performing NMST, a kind of motivation and encouragement is made in the participants for the continuance of the activity. It appears that the rhythm plays a same role as music during training. Some studies have indicated the role of music in reducing the fatigue [10].

## CONCLUSION

Therefore, from the present observations NMST is recommended as a valid and a simple test to evaluate $VO_{2max}$ with high accuracy. This study was a pilot for assessment of the test so, we should involve a large sample in order to introduce the NMST test.

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