The relationship between maximum acceptable work time and physical workload

Hsin-Chieh Wu and Mao-Jiun J. Wang*

Department of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, Taiwan, 30043, ROC.

Keywords: Work time; Physical workload; Relative aerobic strain; Physiological response

For safe job design, it is necessary to know maximum acceptable work time (MAWT) for a given workload. The aim of this study was to establish the relationship between MAWT and physical workload. Cycling tests at six different work rates relative to personal maximum working capacity were performed by 12 young adults in the laboratory. The oxygen uptake (VO₂) in percent of maximum aerobic capacity (%VO₂max), relative heart rate (RHR), and relative oxygen uptake (RVO₂) were collected throughout the test. MAWT was determined by observing the heart rate data during the test. The results show that MAWT was inversely correlated with the %VO₂max, RHR, and RVO₂ (p < 0.01). Three exponential regression models were obtained and their R² values were greater than 0.80. These models suggest that long-hour shift (e.g. 10 hours or greater) should assign less work intensity as compared with that for an 8-hour workday. It is also logical that the workload limit for a 4-hour work shift can be set about 10% VO₂max higher as compared with the suggested limit for an 8-hour workday.

* Corresponding author.
E-mail address: mjwang@ie.nthu.edu.tw. Tel.: 886-3-5742655. Fax: 886-3-5737107.
1. Introduction

To ensure safety and health in the workplace, Brody (1945) first proposed that a suitable safety margin would perhaps be needed in physical demanding jobs. It meant that to determine the maximum workload that can be sustained throughout a workday in a safe and healthy manner is very important. The term “workload” meant the amount of work-related demand taxing on the human being. Several research results, e.g., Michael et al. (1961), Lehmann (1962), Bink (1962), and Ilmarinen (1992) suggested that 33% of the individual’s maximum aerobic capacity (VO$_{2\text{max}}$) should be the acceptable workload for general 8-hour physical work. Jørgensen (1985) also proposed that the upper general tolerance limit over an 8-hour workday, consisting of mixed physical work including manual handling operations, was 30-35% VO$_{2\text{max}}$ (on bicycle legwork or treadmill).

In addition to %VO$_{2\text{max}}$, relative heart rate (RHR) and relative oxygen uptake (RVO$_2$) are also good indices to represent workload intensity. RHR was defined as 
\[(\text{HR}_{\text{work}} - \text{HR}_{\text{rest}})/(\text{HR}_{\text{max}} - \text{HR}_{\text{rest}}) \times 100\%,\]
where HR$_{\text{max}}$ was the maximum heart rate, and HR$_{\text{rest}}$ was the resting heart rate level. The HR$_{\text{work}}$ was the average heart rate during work. Similarly, RVO$_2$ was defined as 
\[(\text{VO}_2\text{work} - \text{VO}_2\text{rest})/(\text{VO}_2\text{max} - \text{VO}_2\text{rest}) \times 100\%.\]
For industrial practice, RHR was frequently chosen as an indicator of physical workload associated with dynamic muscular work (Christensen et al., 2000; Shimaoka et al., 1998). This is due to that HR at work can be measured easier and less costly than the
measurement of VO$_2$. But HR may be affected by several factors that are not merely physically work-related (such as heat, emotion, nutrition, and physical fitness status). These factors should be considered and controlled while collecting the HR$_{work}$ data. It has been shown that the RHR data on a group level are in good agreement with the %VO$_{2\max}$ (ACSM, 1995; Søgaard et al., 1996). Recently, the RHR was proven to be equivalent to RVO$_2$, but not to %VO$_{2\max}$ (Swain and Leutholtz, 1997; Pollock et al., 1998). Generally, the tasks performed at RHR (or RVO$_2$) equal to or greater than 30% can be considered as ‘high’ cardiovascular load for an 8-hour workday (Ilmarinen, 1992; Shimaoka et al., 1998).

Acceptable workload represents the balance between physical workload and cardiorespiratory capacity during 8 hours of work (Aminoff et al., 1998). When this balance approaches, the oxygen uptake (VO$_2$) and heart rate (HR) will maintain a steady state level with a constant work output. After working a very prolonged time, an accumulation of lactic acid in the blood puts an additional load to cardiovascular system and causes a sudden increase in HR. Thus, a markedly higher HR (about 10 beats \( \cdot \) \( \text{min}^{-1} \) above) towards the end of a work shift, as compared to the steady state HR observed during the initial hours of work, is a clear sign of fatigue. This criterion was applied to determine the acceptable workload for an 8-hour workday (Saha et al., 1979).

Likewise, it can be applied to determine the maximum acceptable work time
MAWT. MAWT can be considered as the maximum amount of time in which an individual can sustain without fatigue while undertaking a given workload. This term is different from maximum voluntary work time (or exhaustion time). Once MAWT is determined, the undertaking workload is regarded as the acceptable workload for that period of time.

Since there is a growing trend of adopting flexible working schedules in modern manufacturing environment, some work shift systems nowadays are longer than the traditional 8-hour workday. Taking the semiconductor-manufacturing industry in Taiwan as an example, most companies adopt the four groups and two shifts working system. Operators work 12 hours per day for two consecutive days, then rest for the next two days. For work shifts other than 8 hours, there is a need to know the guidelines about relationship between work time and work intensity. Bink (1962) studied the relationship between work time and work intensity. Based on Bink’s results, Rodgers et al. (1986) recommended that 28%, 30.5%, 33%, and 45% VO$_{2\text{max}}$ were workload limits that can be sustained for 12, 10, 8, and 4 hours, respectively. Is this criteria suitable for workers in Taiwan? We have therefore undertaken a laboratory experiment to investigate whether a relationship between MAWT and physical workload (in terms of %VO$_{2\text{max}}$ or RVO$_2$). On the other hand, using RHR as the alternative workload indicator is very practical and less costly for real world applications. It would be desirable, if a relationship between MAWT
and RHR can be determined. Therefore the MAWT—RHR relationship model was also aimed to obtain here.

2. Method

2.1. Subjects

Twelve volunteer individuals, six males and six females, were chosen as subjects in this study. They were untrained healthy Taiwanese with age ranging from 20 to 30 years. The body height of them matched the typical worker body height distribution in Taiwan. The subject characteristics are listed in table 1. The $HR_{rest}$, $HR_{max}$, $VO_{2rest}$, $VO_{2max}$, and $W_{max}$ were measured in a maximum capacity test, and further explanations are given in the later section. All subjects were informed in detail about the study. They gave their written consents to indicate their awareness of the experimental procedures, and their willingness to participate the study. All subjects were familiar with the experimental procedures before the experimental data were collected.

[Insert table 1 about here]

2.2. Equipment

A pulmonary function testing system, K4 system, (Cosmed Srl, Italy) was used to measure $VO_{2}$, HR, and the respiratory quotient in the experiment. This K4 system has
been validated as an accurate device for VO$_2$ measurement during exercise (Hausswirth et al., 1997). It contains a portable unit, receiving unit, and battery charger unit. A facemask connects a person to the portable unit. A cardiac belt transmits impulses to the portable unit, while the exhaled gas is sampled and mixed into a dynamic micro chamber. Before using the K4 system, it is necessary to calibrate the O$_2$ and CO$_2$ analyzers. The chamber was cleaned before each test. All of the measured data were in real time transmission via radio to the receiver unit for processing and display.

An electrical bicycle ergometer, Ergometrics er800s, (Ergoline, Germany) was used for the incremental and constant cycling tests. The pedaling speed range was from 30 to 130 rpm. The range of work rate (specified in watt in the bicycle ergometer) was from 25 to 999 watts. Seat height, handlebar height and handlebar position were adjustable for subjects between 120 and 210 cm in body height.

2.3. **Maximum capacity test**

This test was aimed to obtain the resting VO$_2$ and HR (VO$_2^{rest}$ and HR$_{rest}$), as well as the maximum VO$_2$ and HR (VO$_2^{max}$ and HR$_{max}$). Each subject was informed that exercises were not permitted within three hours before the maximum capacity test. At first, the subject was seated for 10 min. His/her HR$_{rest}$ and VO$_2^{rest}$ were collected during the last 3 min of the 10-min sitting. He/she then performed an incremental cycling exercise with a
constant pedaling frequency of 60 rpm. The work rate for males was designed with an increase of 10 watts per minute with an initial work rate of 120 watts. The work rate for females was designed with an increase of 5 watts per minute with an initial work rate of 80 watts. These work rate settings were determined through a pilot study procedure prior to the maximal capacity test. It was expected to lead each subject to sustain the incremental cycling exercise for more than 6 minutes and to obtain an approximately steady-state VO$_2$ (Åstrand and Rodahl, 1986). The K4 system was set to continuously collect VO$_2$ and HR at 15-second intervals throughout the test. The approach of a subject’s HR$_{\text{max}}$ and VO$_{2\text{max}}$ was confirmed when at least two of the three following test criteria were satisfied (Heil, et al. 1995): (1) there is no further increase in VO$_2$ and in HR despite a further increase in work rate, (2) the respiratory quotient is over 1.10, and (3) HR$_{\text{max}}$ within 15 beats of age-predicted maximal HR (220–age). When VO$_{2\text{max}}$ is approached, the undertaking work rate (watt) is defined as his/her maximum working capacity (W$_{\text{max}}$).

2.4. Experimental tasks and procedure

Once a subject’s W$_{\text{max}}$ was determined, he/she was assigned the cycling tests at 20%, 30%, 40%, 50%, 60%, and 70% W$_{\text{max}}$ on six separate days. During each cycling test, the subject maintained a constant pedaling frequency of 60 rpm. The K4 system was set to
continuously collect VO₂ and HR at 30-second intervals throughout the test. A break of 10 minutes was allowed after 50 minutes of work in every hour. This is to simulate a standardized work-rest schedule for a prolonged continuous dynamic work (Åstrand and Rodahl, 1986). The laboratory environment was air conditioned during the experiment with ambient temperature in comfortable range (25 ± 1 ºC). The cycling test would terminate when the subject felt exhausted and stopped voluntarily. Each test lasted about 0.5~12 hours, depending on the intensity of work rate (%Wₘₐₓ) and the subject’s endurance ability. A total of 72 cycling tests (2 genders × 6 subjects × 6 work rates) and about 240 work hours were performed.

2.5. Measurements and statistics

The dependent variables in the experiment included MAWT, %VO₂ₘₐₓ, RHR, and RVO₂. The MAWT was defined as the time from the onset of the test until subject’s HR was 10 beats · min⁻¹ higher than the steady state HR during the initial hours of work. The %VO₂ₘₐₓ was defined as VO₂work in percent of the VO₂ₘₐₓ. The VO₂work was calculated by averaging the VO₂ during the MAWT. Since the oxygen deficit occurred at the first 2 to 4 minutes of work, the VO₂ at the first 5 minutes of work was not included in VO₂work. HRₜₐₜ was also obtained by the same way as the VO₂work. RHR was defined as (HRₜₐₜ − HRₗₑₛₜ) / (HRₘₐₓ − HRₗₑₛₜ) × 100%, and RVO₂ was defined as (VO₂ₜₐₜ − VO₂ₗₑₛₜ) /
(VO₂_{max} − VO₂_{rest}) \times 100\%. Analyses of variance were performed to evaluate the effects of work rate on the dependent variables. The significant level was set as \(\alpha=0.05\). The Pearson product-moment correlations were conducted to obtain the correlation coefficients between MAWT and the other variables. Forward regression analyses were conducted to find the best fitted function for predicting MAWT. All of the data analyses were completed using the statistical analysis software, STATISTICA 5.0.

3. Results

In this study, the MAWT was determined using physiological method that specified an initial sign of fatigue as a markedly higher HR towards the end of a work shift, as compared to the steady state HR observed during the initial hour of work. When the work rate was 20\%, 30\%, 40\%, or 50\% W_{\text{max}}, the heart rate maintained steady state after the fifth minute of work. And a clear sign of fatigue occurred after 1~10 hours of work, depending on the level of work rate. However, as the work rate was 60\% and 70\% W_{\text{max}}, the heart rate increased rapidly at the first five minutes and continued to increase gradually after the fifth minute of work until the end of work. No clear sign of fatigue can be observed from the heart rate data throughout the test, because no obvious steady state HR was found at 60\% and 70\% W_{\text{max}}. Thus, the MAWT and the other response data at these two work rate levels were not available.
3.1. MAWT and physical workload at different work rates

Table 2 shows the descriptive statistics (mean ± SD) of MAWT and physical workload (represented by %VO$_{2\text{max}}$, RHR, and RVO$_2$) at 20%, 30%, 40%, and 50% W$_{\text{max}}$ for the male and female subjects. The work rate had a statistically significant effect (p < 0.05) on all of the dependent variables. The data show that MAWT tended to decrease from 20% W$_{\text{max}}$ to 50% W$_{\text{max}}$. On the other hand, %VO$_{2\text{max}}$, RHR, and RVO$_2$ were observed to increase systematically, as W$_{\text{max}}$ increased from 20% to 50%. The subject effect was also statistically significant (p < 0.05) on all of the dependent variables.

[Insert table 2 about here]

The Pearson correlation coefficients between MAWT and the other variables are listed in table 3. The data exhibit that MAWT was significantly correlated (p < 0.01) with %W$_{\text{max}}$ (r = -0.91), %VO$_{2\text{max}}$ (r = -0.88), RHR (r = -0.89), and RVO$_2$ (r = -0.89). All of the physiological responses at work (%VO$_{2\text{max}}$, RHR, and RVO$_2$) were positively correlated with %W$_{\text{max}}$ (p < 0.01).

[Insert table 3 about here]

3.2. The relationship between MAWT and physical workload
Based on the experimental results, the three physiological responses obtained at work (%VO$_{2\text{max}}$, RHR, and RVO$_{2}$) were found to be inversely correlated with MAWT. Using %VO$_{2\text{max}}$, RHR, and RVO$_{2}$ as the physical workload measures, the relationship between MAWT and physical workload can be obtained by regression analysis. The experimental data and the fitted curves are illustrated in figures 1, 2, and 3. The three MAWT prediction models are:

MAWT = 95.33 × $e^{-7.28 \times \%VO_{2\text{max}}}$, \hspace{1cm} R$^2$ = 0.83, \hspace{1cm} Model (1).

MAWT = 26.12 × $e^{-4.81 \times \text{RHR}}$, \hspace{1cm} R$^2$ = 0.87, \hspace{1cm} Model (2).

MAWT = 37.80 × $e^{-6.36 \times \text{RVO}_2}$, \hspace{1cm} R$^2$ = 0.83, \hspace{1cm} Model (3).

The standard error of the estimate (SEE) of the three models is 1.09, 1.07, and 1.12 hour respectively. The common characteristics of the three models are summarized as follows:

(a) There is a continuous decrease in MAWT with an increase in physical workload.

(b) With an increase in physical workload, the MAWT decreases rapidly at lower workload, and then it decreases slowly at higher workload.

(c) The MAWT approaches zero, as the physical workload is extremely heavy.

(d) Each model’s standard error of the estimate (SEE) is about 1 hour.

(e) All of the three fitted models can explain more than 80% of the variations in predicting MAWD.
4. Discussion

There was no significant difference in all the dependent variables (i.e., MAWT, %VO$_{2\text{max}}$, RHR, and RVO$_{2}$) between male and female subjects in this study. This means that the relative efforts exerted by male and female subjects were very close, when they performed the cycling tests at the same percentage of their maximal work rates. Åhsberg and Gamberate (1998) also indicated that men and women did not differ significantly with respect to their ratings of perceived fatigue, as cycling at the same level of relative work rate. Thus, our suggested workload limit in terms of %VO$_{2\text{max}}$, RHR, or RVO$_{2}$ is applicable to both males and females.

Based on the proposed MAWT prediction models, the corresponding workload levels that can be sustained for 12, 10, 8, and 4 hours are summarized in table 4. The term work time in table 4 is a prolonged period of continuous working with a standardized work-rest schedule (50 min work / 10 min rest in every hour). The data from Rodgers et al. (1986) are also included in table 4 for comparison. Our suggested upper limits in %VO$_{2\text{max}}$ for 12, 10, 8, and 4-hour workdays are 28.5%, 31%, 34%, and 43.6%. They are
similar to those (28%, 30.5%, 33%, and 45%) recommended by Rodgers et al. (1986).

The workload limit in %VO₂max for a 12-hour workday is about 5% less than that for an 8-hour workday. Besides, the workload limit in %VO₂max for a 10-hour workday is about 3% less than that for an 8-hour workday, as shown in table 4. The data suggest that long-hour shifts (e.g. 10 hours or greater) should assign less work intensity as compared with that for an 8-hour workday. Further, it is also logical that the workload limit for a 4-hour work shift can be set about 10% VO₂max higher as compared with the suggested limit for an 8-hour workday. This is also in agreement with the suggestions of Rodgers et al. (1986). It is quite interesting to show that the relationship between MAWT and %VO₂max for Taiwanese populations is approximately the same as that for Western populations. It means that Taiwanese young adults and Western people can sustain about the same working time without fatigue while undertaking the physical workloads with the same percentage of their maximal aerobic capacity.

Furthermore, table 4 shows that the value of RHR and RVO₂ tended to be about 10% less than the corresponding value of %VO₂max. This is due to that a person at rest has a nonzero heart rate and a nonzero VO₂. For example, an untrained healthy individual with a 10-MET (1 MET = basic metabolic rate at rest) capacity is at 10% of VO₂max at rest (1 MET/10 METs), and at 0% of RHR and RVO₂. Thus, a 10% discrepancy is introduced at
the resting end of the relationship between RHR (or RVO₂) and \( \%\text{VO}_2\text{max} \). Swain, et al. (1997) has also reported that RHR is equivalent to RVO₂, and both of them are always less than the value of \( \%\text{VO}_2\text{max} \). The discrepancy between RHR (or RVO₂) and \( \%\text{VO}_2\text{max} \) would be inversely related to fitness level. Therefore, it is reasonable that the safety limits expressed in terms of RHR (or RVO₂) should be less than that of \( \dot{\text{VO}}_2\text{max} \).

The suggested workload limit in terms of RHR for an 8-hour workday (24.5% RHR) is 5.5% less than that (30% RHR) suggested for nursery education work (Shimaoka et al., 1998). This discrepancy can be explained by the fact that nursery education work doesn’t involve so much muscular effort as that of leg cycling work. Since the experimental data were obtained from cycling tests, the proposed models are likely to be most applicable to tasks involving mainly lower limb muscular effort such as rapid and prolonged walking or climbing stairs. Moreover, the relationship between MAWT and RHR (model (2)) is particular valuable for real world application, because collecting heart rate data at work is more convenient and inexpensive than measuring oxygen uptake. This model can be used to estimate the MAWT for various workloads in RHR.

5. Conclusion

The finding of this study confirmed that MAWT was significantly correlated with the relative aerobic strains (i.e., \( \%\text{VO}_2\text{max} \), RHR, and RVO₂) with an exponential decrease
relationship. Three MAWT prediction models were obtained. Based on the predicted data, the suggested upper limits of %VO$_2$max for dynamic work lasting 12, 10, 8, and 4 hours are 28.5%, 31%, 34%, and 43.6%, respectively. The results are similar to the recommendation proposed by Rodges, et al. (1986). The suggested RHR and RVO$_2$ limits are less (about 10% lower) than the upper limit of %VO$_2$max for the same period of work. The obtained relationship between MAWT and physical workload can be used to determine guidance in concerning the acceptable (or reasonable) combinations of workload and duration for dynamic muscular work involving mainly lower limb muscular effort. The obtained relationship between MAWT and RHR can provide a handy tool for evaluating physical workload by simply measuring heart rate data.

Acknowledgements

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Table 1. Characteristics of the subjects.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>6 males</th>
<th>6 females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>27.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Body height (cm)*</td>
<td>170.9</td>
<td>7.2</td>
</tr>
<tr>
<td>Body weight (kg)*</td>
<td>67.2</td>
<td>9.6</td>
</tr>
<tr>
<td>HR_{rest} (beats/min)</td>
<td>78.8</td>
<td>7.8</td>
</tr>
<tr>
<td>HR_{max} (beats/min)</td>
<td>187.5</td>
<td>6.2</td>
</tr>
<tr>
<td>VO_{2rest} (liters/min)</td>
<td>0.277</td>
<td>0.051</td>
</tr>
<tr>
<td>VO_{2max} (liters/min)*</td>
<td>2.802</td>
<td>0.232</td>
</tr>
<tr>
<td>W_{max} (watts)*</td>
<td>209.2</td>
<td>25.0</td>
</tr>
</tbody>
</table>

*A significant difference between males and females at $\alpha = 0.05$ (t-test).*
Table 2. MAWT, %VO\textsubscript{2max}, RHR, and RVO\textsubscript{2} at different %W\textsubscript{max} for male and female subjects.

<table>
<thead>
<tr>
<th>Gender</th>
<th>%W\textsubscript{max}</th>
<th>MAWT (hour)</th>
<th>%VO\textsubscript{2max} (%)</th>
<th>RHR (%)</th>
<th>RVO\textsubscript{2} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>20%</td>
<td>8.15 ± 0.76</td>
<td>34.89 ± 3.17</td>
<td>24.41 ± 3.37</td>
<td>27.72 ± 3.50</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>3.59 ± 0.32</td>
<td>43.99 ± 4.18</td>
<td>38.15 ± 6.22</td>
<td>37.84 ± 4.25</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>2.35 ± 0.60</td>
<td>50.26 ± 6.81</td>
<td>50.52 ± 4.70</td>
<td>44.84 ± 7.16</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1.20 ± 0.41</td>
<td>58.71 ± 5.23</td>
<td>65.61 ± 5.49</td>
<td>54.20 ± 5.49</td>
</tr>
<tr>
<td>Female</td>
<td>20%</td>
<td>8.73 ± 1.12</td>
<td>35.94 ± 2.55</td>
<td>26.82 ± 2.97</td>
<td>24.14 ± 4.60</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>3.93 ± 0.85</td>
<td>44.40 ± 2.68</td>
<td>40.37 ± 2.69</td>
<td>34.27 ± 1.68</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>2.26 ± 0.58</td>
<td>51.38 ± 1.10</td>
<td>50.40 ± 3.75</td>
<td>42.43 ± 2.91</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1.25 ± 0.60</td>
<td>61.61 ± 3.09</td>
<td>65.05 ± 4.35</td>
<td>54.66 ± 2.38</td>
</tr>
</tbody>
</table>

The descriptive statistics data are ‘mean ± SD’.
Table 3. The Pearson product-moment correlation matrix.

<table>
<thead>
<tr>
<th></th>
<th>%W&lt;sub&gt;max&lt;/sub&gt;</th>
<th>MAWT</th>
<th>%VO&lt;sub&gt;2max&lt;/sub&gt;</th>
<th>RHR</th>
<th>RVO&lt;sub&gt;2&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>%W&lt;sub&gt;max&lt;/sub&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAWT</td>
<td>-0.91*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%VO&lt;sub&gt;2max&lt;/sub&gt;</td>
<td>0.92*</td>
<td>-0.88*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RHR</td>
<td>0.96*</td>
<td>-0.89*</td>
<td>0.92*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RVO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.93*</td>
<td>-0.89*</td>
<td>0.97*</td>
<td>0.91*</td>
<td>1</td>
</tr>
</tbody>
</table>

* significant at p < 0.01
Table 4. The suggested workload limits for 12, 10, 8, and 4 hours of work.

<table>
<thead>
<tr>
<th>Work time (hour)</th>
<th>Workload limits from the present study (a)</th>
<th>Workload limits from Rodgers et al. (1986) (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%VO$_{2\text{max}}$</td>
<td>RHR</td>
</tr>
<tr>
<td>12</td>
<td>28.5%</td>
<td>16%</td>
</tr>
<tr>
<td>10</td>
<td>31%</td>
<td>20%</td>
</tr>
<tr>
<td>8</td>
<td>34%</td>
<td>24.5%</td>
</tr>
<tr>
<td>4</td>
<td>43.5%</td>
<td>39%</td>
</tr>
</tbody>
</table>

(a) The data of this study were collected from Taiwanese population. The mean age of the subjects was 26 years. The mean VO$_{2\text{max}}$ (milliliters of oxygen per kilogram of body weight per minute) of the male and female subjects was 42 ml · kg$^{-1}$ · min$^{-1}$ and 37 ml · kg$^{-1}$ · min$^{-1}$, respectively.

(b) The data of Rodgers et al (1986) were from Western Europe industries. The mean age of the subjects was 35 years. The mean VO$_{2\text{max}}$ of the male and female subjects was 40 ml · kg$^{-1}$ · min$^{-1}$ and 31 ml · kg$^{-1}$ · min$^{-1}$, respectively.
Figure 1. The relationship between MAWT and %VO$_{2\text{max}}$. 

Model (1) 

MAWT = 95.33e$^{-7.28(%VO_{2\text{max}})}$

R$^2 = 0.83$

SEE = 1.09 hour
Figure 2. The relationship between MAWT and RHR.
$\text{MAWT} = 37.80e^{-6.36(RVO^2)}$

$R^2 = 0.83$

SEE = 1.12 hour

Figure 3. The relationship between MAWT and RVO$_2$. 