**EXAMINING THE RELATIONSHIP BETWEEN THE MECHANICAL AND METABOLIC ENERGY EXPENDITURE OF WALKING AT VARIOUS VELOCITIES**

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## INTRODUCTION

It has previously been acknowledged that individuals tend to select a movement pattern in which their metabolic cost or rate of oxygen consumption ($VO_2$) is minimized, otherwise known as the "optimal phenomenon"[1,2]. Any subsequent changes in the movement will lead to an increased $VO_2$ and thus a "U-shaped" economy curve. By combining the metabolic cost with the mechanical energy expenditure (MEE) in the calculation of "mechanical efficiency" (MEFF), the knowledge regarding a movement pattern will be further increased. It would also be expected that valid MEFF results would demonstrate an optimal efficiency at an individual's self-selected normal gait pattern. Unfortunately, very few studies have examined the MEFF of human motion. The purpose of this study was to examine the ability of two MEE methods in calculating MEFF of walking over a range of five velocities. It was hypothesized that the more valid estimate of MEE would correlate highly with $VO_2$ and derive estimates of MEFF that would produce an inverted U-shaped curve with the maximum efficiency at the normal walking velocity.

## MATERIAL AND METHODS

Ten healthy and active subjects (5 female and 5 male) were required to walk at five velocities: 40% below normal (B40), 20% below normal (B20), normal, 20% above normal (A20) and 40% above normal (A40). Velocity was controlled with the use of two photoelectric Micro Switches (Honeywell) and with a metronome matched to a subject's step rate. Metabolic cost was calculated by indirect calorimetry during the 5 walking conditions and at a resting metabolic rate. Expired gas samples were collected in Mylar bags for one minute after 5 minutes was provided to reach the exercise steady state. Applied Electrochemistry oxygen and carbon dioxide analyzers were used to determine the gas concentrations while ventilation volumes were determined with a chain-compensated gasometer Tissot Tank. MEFF results were calculated by dividing MEE by the metabolic energy expenditure during one complete stride. MEE was derived from the absolute power method (APM) and absolute work method (AWM) as discussed in a previous study. The effects of velocity and the interrelationship between aerobic demand and MEE were determined while a trend analysis was used to analyze the prevalent relationship existing in the mean MEFF results of each subject and for the combined subjects normalized to their respective maximum efficiency values.

## RESULTS

Both mechanical and metabolic calculations of energy expenditure increased curvilinearly with walking velocity (Figure 1). However, a greater relationship was evident between $VO_2$ and the APM MEE (r=0.910). A significant difference was found between the two MEFF calculations ($P \leq 0.05$). The AWM provided efficiencies that were on average 14, 17 and 28% greater than the APM and that erroneously exceeded 100%. Trend analysis results are presented in Table 1 for individual subjects. With the APM, only three subjects achieved their maximum MEFF in the A40 condition, whereas in the AWM, the maximum MEFF of all ten subjects occurred in the A40 condition.

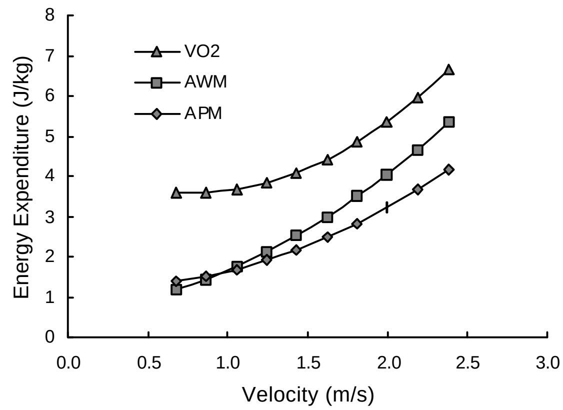


Figure 1. Regression lines best-fitting the mean subject energy expenditure results of the metabolic and mechanical analyses.

Table 1. Trend analysis results of individual MEFF curves.

| Subject | APM | | AWM | |
|---|---|---|---|---|
| | Trend | P value | Trend | P value |
| 1 | Quartic | ≤0.050 | Linear | ≤0.001 |
| 2 | Cubic | ≤0.025 | Cubic | ≤0.025 |
| 3 | Quartic | ≤0.050 | Quartic | ≤0.025 |
| 4 | Quartic | ≤0.010 | Linear | ≤0.001 |
| 5 | Linear | ≤0.001 | Quadratic | ≤0.010 |
| 6 | Quadratic | ≤0.025 | Linear | ≤0.010 |
| 7 | Quadratic | ≤0.001 | Linear | ≤0.010 |
| 8 | Quartic | ≤0.001 | Quartic | ≤0.001 |
| 9 | Quartic | ≤0.001 | Linear | ≤0.001 |
| 10 | Quartic | ≤0.050 | Linear | ≤0.001 |
| Total | Quadratic | ≤0.025 | Linear | ≤0.001 |

## DISCUSSION AND CONCLUSION

The strong correlation derived between MEE of the APM and $VO_2$ contradicted previous research[3]. The APM produced consistently lower MEFF values which better represented the notion that MEFF of human motion should not exceed 30%[1]. Also, the optimal phenomenon was clearly evident in the MEFF calculated with APM where 5 of the 10 subjects had their efficiencies maximized at their self-selected normal walking velocity. No subjects achieved their maximum efficiency during the normal condition when using the AWM to determine MEFF. Therefore, the MEE of the APM provided a valid estimate of the MEFF.

## REFERENCES

[1]CAVANAGH PR & KRAM R (1985) *Med. Sci. Sports Exerc.* 17:326-331.
[2]HOLT et al. (1991) *Med. Sci. Sports Exerc.* 23:491-498.
[3]MARTIN et al. (1993) *Med. Sci. Sports Exerc.* 25:491-498.