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On the utility of cardiorespiratory surrogates of whole-body energy expenditure

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Abstract
Due to environmental and scenario constraints, direct measures of the metabolic demands of work can be difficult or impossible. Fortunately, cardiorespiratory variables respond in a predictable fashion with work rate, and can serve as surrogate indices for approximating energy expenditure (e.g. heart rate and minute ventilation). However, a failure to fully explore the utility of these indices during field-based work is a major limitation within the literature. Thus, this investigation was aimed at evaluating the transferability of predictive equations developed in the laboratory to a series of fire-fighting simulations conducted in the field.

Keywords
expenditure, utility, cardiorespiratory, whole, body, energy, surrogates

Disciplines
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On the utility of cardiorespiratory surrogates of whole-body energy expenditure

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Introduction
Due to environmental and scenario constraints, direct measures of the metabolic demands of work can be difficult or impossible. Fortunately, cardiorespiratory variables respond in a predictable fashion with work rate, and can serve as surrogate indices for approximating energy expenditure (e.g. heart rate and minute ventilation). However, a failure to fully explore the utility of these indices during field-based work is a major limitation within the literature. Thus, this investigation was aimed at evaluating the transferability of predictive equations developed in the laboratory to a series of fire-fighting simulations conducted in the field.

Methods
Prediction equations using heart rate and minute ventilation were derived using 15 subjects, during lower-body, load-carriage exercise in the laboratory. These equations were then used to predict the metabolic demand of three fire-fighting simulations (70-mm hose drag, hazmat incident, bushfire hose drag) performed by 48 firefighters (male and female); 16 per simulation. During each simulation, respiratory gas exchange and cardiorespiratory variables were measured, and these data were compared with predictions of metabolic demand, leading to the derivation of mean residual prediction errors for oxygen consumption during the performance of these work simulations.

Results and Discussion
Heart rate predictions over-estimated oxygen consumption during each simulation (mean prediction error: 0.71 ±0.12 L·min⁻¹; p<0.05). These artefacts were caused by the participation of the heart in homeostatic processes beyond oxygen delivery. Since the metabolic demand of these tasks often exceeded Owles point, then minute ventilation predictions derived using data obtained beyond this point also over-estimated metabolic demand (mean prediction error: 0.59 ±0.11 L·min⁻¹; p<0.05). These results indicate that generalised predictions of metabolic rate have little utility under these circumstances, and confirm the need for an individual calibration curve for each worker to be evaluated, thereby strengthening the predictive precision of these indices.

Conclusion
This investigation evaluated the transferability of cardiorespiratory predictive equations developed in the laboratory to a series of occupational tasks. It appears that satisfactory predictive precision can only be achieved by utilising predictive equations derived from individual regression slopes that are specific to the worker under investigation, and that have been generated using data that are most closely reflective of the task in question, and the intensity at which that task was performed. A failure to satisfy any one of these criteria adversely affects the predictive precision of these surrogate indices.