

Correlation of Borg rating to Physiologic Cost Index (PCI) and Total Heart Beat Index (THBI) for the Walking Index for Spinal Cord Injury (WISCI)

¹Anthony S. Burns MD, ²Myeong Ok Kim MD, ¹Ralph J. Marino MD, ¹John F. Ditunno MD

Departments of Rehabilitation Medicine, ¹Jefferson Medical College of Thomas Jefferson University, The Regional SCI Center of the Delaware Valley, Philadelphia, PA; ²Inha University Hospital, Incheon, Korea

ABSTRACT

Objective: To correlate Borg rating (perceived exertion) to other estimates of energy expenditure (PCI, THBI) within the context of the WISCI.

Design: Prospective testing of perceived exertion and estimated energy expenditure for chronic SCI.

Participants/methods: Sixty-five subjects with chronic SCI (≥ 12 months duration) ambulated at *submaximal* and *maximal* WISCI levels. The WISCI is a hierarchical scale (0-20) measuring ambulatory capacity following SCI. *Submaximal* and *maximal* levels are defined as the level assigned the lowest Borg rating and the highest level at which a subject can safely ambulate (minimum 10m), respectively. Subjects ambulated 100m or as far as possible (distance recorded) and provided *submaximal* and *maximal* Borg ratings. Ambulatory speed (m/sec) and continuous heart rate were measured. PCI (Δ HR/velocity) and THBI (total heartbeats/distance) were calculated. The Borg was correlated to PCI and THBI using Spearman (nonparametric) correlation coefficients (skewed data).

Results: Correlations for Borg to PCI were 0.553 (*submax*) and 0.531 (*max*), and for Borg to THBI 0.544 (*submax*) and 0.559 (*max*). Correlations between PCI and THBI were 0.867 (*submax*) and 0.935 (*max*). All coefficients were significant ($p < 0.001$).

Conclusion: The limited correlation of Borg to PCI/THBI suggests the Borg has limitations for estimating energy expenditure, when utilizing the WISCI. The reasons warrant further investigation. As expected, PCI and THBI strongly correlated. Future experiments correlating PCI/THBI to VO₂ max may (1) confirm their utility for estimating energy expenditure, and (2) support their superiority to the Borg for the WISCI.

INTRODUCTION

The Walking Index for Spinal Cord Injury (WISCI) is a 21-level hierarchical scale for the precise measurement of walking function following SCI.^{1,2,3} It was designed for use in clinical trials. The Borg rating of perceived exertion is widely used to estimate energy expenditure during exertion. Within the context of the WISCI, we studied the correlation of the Borg to two other measures of estimated energy expenditure, the Physiologic Cost Index (PCI)^{4,5} and the Total Heart Beat Index (THBI).⁶ The PCI and THBI are additional parameters for estimating energy expenditure during walking. PCI should be calculated under steady-state conditions, but THBI is reported to be valid under both steady and non-steady state conditions.⁶

SUBJECTS & METHODS

Inclusion/exclusion criteria

Individuals with chronic SCI (≥ 12 month duration) were recruited from the Regional SCI Center of the Delaware Valley, Thomas Jefferson University, Philadelphia PA. Inclusion criteria included a history of traumatic SCI, motor incomplete status (AIS C or D), a motor level of C4 to L1 inclusive, and a history of independent lower extremity weight-bearing (standing or ambulating) \geq once a week. Subjects were excluded (1) if they were taking medication that could affect heart rate, i.e., β -blockers, Ca⁺⁺ channel blockers; (2) if they had heart disease, uncontrolled asthma, or any other medical condition that could limit the ability to ambulate safely; and (3) if the baseline WISCI level for community ambulation was 20, the highest possible level. The study protocol was approved by the institutional review board and informed consents were obtained prior to testing.

Study Demographics

The study cohort (n = 65) had an average age of 44 years (range 19-70) and was predominantly male (81.5%, n = 53). Injury etiologies included: MVA (32.3%, n = 21), Falls/Falling Object (26.2%, n = 17), Violence (13.8%, n = 9), Water-related (4.6%, n = 3), Sports (9.2%, n = 6), Other (13.8%, n = 9).

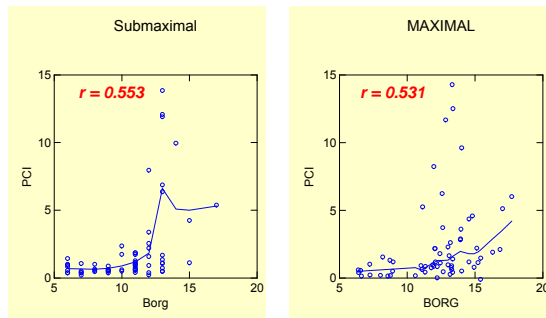
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Methods

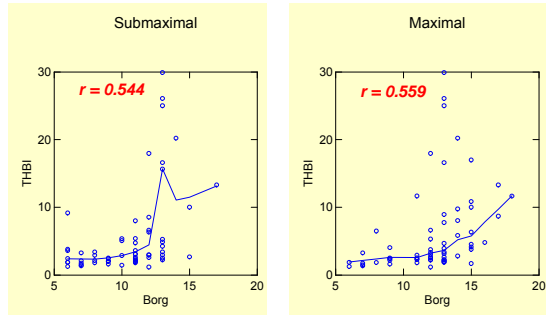
The sub-max-WISCI is the level rated the lowest, using the Borg scale, for 10m (preliminary assessment). The max-WISCI is the highest level for which a subject can safely walk 10m, as determined by the therapists. For testing, subjects ambulated back and forth along a marked 10m length for 10 laps (100m), or alternatively as far as possible. Continuous heart rate (HR) was recorded using a Polar™ heart rate monitor (Polar Electro, Kempele, Finland). Durations for turns at the end of each length and the accompanying heartbeats were excluded from analysis. Individuals rested between max-WISCI and self-WISCI until HR returned to baseline (± 5 beats/min). Physiologic Cost Index (PCI) was calculated using the equation, PCI (beats/meter) = (steady state HR – resting HR)/ambulatory velocity. Steady state HR was the average HR of the last two lengths, and resting HR was the initial HR. If subjects couldn't walk the full 100m, the average HR of the last two lengths was still used as steady state HR. Total heart beat index (THBI) was calculated using the equation, THBI (beats/meter) = total heartbeats during testing/distance traveled. Borg rating was ascertained again at the end of testing for correlations to PCI & THBI.

RESULTS

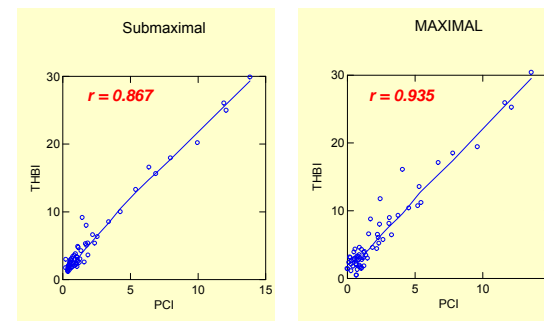
Borg-to-PCI correlations (Spearman):



Borg-to-THBI correlations (Spearman):



PCI-to-THBI correlations (Spearman):



DISCUSSION & CONCLUSION

The correlation of the Borg to PCI and THBI was moderate but significant ($p < 0.001$). The reason why the observed correlations were not stronger is unclear. Possible explanations include limitations of the Borg for estimating energy expenditure following incomplete SCI or alternatively, limitations of the PCI/THBI for estimating energy expenditure following incomplete SCI. Regardless, the excellent correlations (0.867 – 0.935) between the PCI and THBI provide strong evidence that these two parameters measure the same variable. Studies are underway to compare both the Borg and PCI/THBI to the “gold standard” of energy expenditure, oxygen consumption (VO₂). These studies will help (1) validate the use of these parameters following incomplete SCI and (2) determine which specific parameter (Borg vs. PCI vs. THBI) has the best reliability/sensitivity/validity for incomplete SCI. Important considerations given that VO₂ measurement is not widely available; a current barrier to its usage in clinical studies and trials.

An additional and interesting observation was the variability of PCI and THBI values for higher Borg ratings, particularly 13 (somewhat hard). Indeed, the highest observed PCI and THBI values occurred at this level. This suggests that some individuals exert significant effort to ambulate at this level, as reflected in their marked HR response (Δ PCI/THBI) but only rated their effort as somewhat hard (Borg). This suggests a possible disconnect between the subjective Borg rating & the more objective parameters.

Conclusion

The correlation of the Borg to alternative parameters of energy expenditure (PCI, THBI) was moderate following incomplete SCI. Future studies are needed to compare Borg/PCI/THBI to VO₂ to validate their usage for estimating energy expenditure following incomplete SCI.

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