Validity of values for metabolic equivalents of task during submaximal all-extremity exercise and reliability of exercise responses in frail older adults

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Validity of Values for Metabolic Equivalents of Task During Submaximal All-Extremity Exercise and Reliability of Exercise Responses in Frail Older Adults

Marissa E Mendelsohn, Denise M Connelly, Tom J Overend, Robert J Petrella

Background and Purpose. Physical therapists and rehabilitation professionals in hospital and long-term care centers are using all-extremity semirecumbent exercise machines in their treatment programs. This study was undertaken to investigate the concurrent validity of values for software-generated metabolic equivalents of task (MET) from an all-extremity semirecumbent exercise machine and directly measured values for MET from a portable metabolic unit across a range of submaximal exercise intensities. A second purpose of this study was to determine the test-retest reliability of oxygen consumption and heart rate responses in older adults between standardized sessions of submaximal all-extremity aerobic exercise.

Subjects and Methods. The study participants were 18 older adults (mean age=82 years, SD=5; 3 women, 15 men) who were living in long-term care centers and who completed 2 test sessions of a standardized exercise protocol 1 week apart. The exercise protocol included a warm-up period, three 4-minute stages of exercise at incremental workload levels, and a cool-down period. The breath-by-breath metabolic data from the portable metabolic unit, heart rate, MET values from the exercise machine, Borg Rating of Perceived Exertion, and watts were recorded continuously throughout the exercise protocol.

Results. The concurrent validity of the MET values from the exercise machine and the portable metabolic unit ranged from very good to excellent on both day 1 and day 2 ($r=.85-.97$). The test-retest reliability of subjects’ heart rate responses and MET values from the portable metabolic unit was moderate to high across submaximal exercise intensities (intraclass correlation coefficients $[2,1]=.85-.91$).

Discussion and Conclusion. The exercise machine software-generated MET values were representative of directly measured oxygen consumption values across a range of submaximal intensities during all-extremity semirecumbent exercise in older adults with multisystem impairments.
Aerobic exercise options are limited for older adults with multisystem impairments, such as cognition, balance, weight-bearing ability, coordination, strength (force-generating capacity), or cardiorespiratory function. Available aerobic exercise options include using traditional exercise bikes, rowing machines, or steppers; walking or using stairs; using arm or leg ergometers in a sitting position; or using treadmills with body-weight-support systems. Simultaneous use of the arms and legs during all-extremity semirecumbent exercise would decrease localized muscle pain or fatigue associated with arm cranking or leg cycling exercise, increase the volume of muscle mass involved in exercise, reduce the likelihood of discontinuation of exercise because of localized arm or leg muscle pain or fatigue, and eliminate the requirement for partial to full weight-bearing capability to participate in aerobic exercise. Aerobic fitness equipment that could accommodate standing balance and lower-extremity impairments and promote whole-body exercise for optimal aerobic fitness training would fill a current gap in exercise equipment options for older adults.

Exercise that can be performed by older adults with multiple impairments will be important for addressing morbidity related to frailty with aging, including dependency, disability, falls, hospitalization, admission to long-term care centers, and associated mortality. There is evidence that exercise training, largely resistance exercise, in older adults in institutions is important for maintaining physical performance. The few available studies on aerobic exercise training in older adults (>80 years of age) have shown increased peak oxygen consumption (VO2) and decreased systolic blood pressure (BP) as well as a relative increase in peak VO2 (14% for men and 13% for women compared with control groups). Residents of assisted-living facilities (mean age=85.5 years, SD=6.6) who exercised ≥9 minutes per week using an all-extremity semirecumbent machine had significantly improved mobility (P=.002) compared with those who exercised for shorter durations.

All-extremity semirecumbent exercise machines, such as the Biostep Clinical Pro Semi-Recumbent Elliptical Cross Trainer and the NuStep TRS 4000 Recumbent Cross Trainer, provide a new mode of seated aerobic exercise training with both arms and legs contributing to work output. These exercise trainers are ideal for accommodating impairments of the lower or upper extremities, weight-bearing ability, balance, coordination, or gait in older adults. However, research addressing the validity of software-generated aerobic fitness values and the reliability of these values during all-extremity exercise is limited. Therefore, this study was undertaken to investigate the concurrent validity of values for software-generated aerobic fitness values and the reliability of these values during all-extremity exercise is limited. The American College of Sports Medicine (ACSM) guidelines for absolute and relative contraindications for exercise testing were used as exclusion criteria. The absence of these exclusion criteria, including a range of cardiac, neurological, and musculoskeletal symptoms and conditions, was confirmed by each subject’s physician. The number of subjects required for the study was determined as described by Hulley et al (Appendix 6.C, Tab. 6.C: α=.05, power=80%). The primary variable was the correlation coefficient (Pearson r), indicating the minimum expected agreement between software-generated NuStep and directly-measured Klb MET values. Thirteen subjects were required to declare a Pearson r correlation coefficient of ≥.70 to be statistically significant. However, with an expected dropout rate of about 30% in this older population, a minimum sample size of 17 subjects was required.

The demographic characteristics of the subjects (Tab. 1), including their age, height, body mass, type of gait aid, date of admission to long-term care center, number of health conditions, and daily medications, were obtained from a review of their medical charts. Subjects were visited individually in their rooms to complete the MMSE. Informed written consent was obtained from all subjects prior to participation.

Over the duration of the study, 25 subjects were recruited. Several subjects withdrew at various stages of testing, which required continued...
recruitment to obtain the calculated sample size. Seven subjects withdrew from the study; 3 were not comfortable wearing the face mask, 2 asked to stop exercising 4 minutes into the required 12 minutes of exercise, 1 had a nonsymptomatic irregular HR response during exercise, and 1 was not well enough to complete the testing sessions. No adverse events associated with exercise testing occurred during the study. Data were collected for 18 subjects (15 men: mean age = 82.2 years, SD = 5.9, range = 73–93; 3 women: mean age = 83.7 years, SD = 1.2, range = 83–85). The sex ratio in our group of subjects was not representative of the usual mix in older age because 83% of our study subjects were men recruited from a veteran’s care program. The study group had an average of 7.7 (SD = 2.8, range = 4–15) chronic health conditions and took a daily average of 11.8 (SD = 4.3, range = 5–19) prescription medications, including β-blockers (n = 14).

Instrumentation

The NuStep is a hybrid semirecumbent bicycle and stair climber machine (Fig. 1) with a range of 10 workload levels. Each arm handle is coupled with a contralateral foot pedal, allowing the user to exercise the upper and lower extremities by using a reciprocal forward and backward motion. Exercise parameters displayed continuously on the NuStep liquid crystal display (LCD) panel include stepping rate, workload level, and accumulated exercise duration. To obtain continuous feedback for HR during exercise, subjects wore an HR monitor (Polar Vantage NV) around the chest at the level of the xiphisternum. The Polar Vantage NV chest strap relayed HR via telemetry, and the HR was displayed on the NuStep LCD panel.

The NuStep LCD touch screen panel could be manipulated to show instantaneous MET values, watts, total number of steps taken, or expended calories. The NuStep instantaneous MET values were software generated from power output (watts) and subject body mass.

The K4b² is a portable, breath-by-breath metabolic system for measuring \( \dot{V}O_2 \) and carbon dioxide production, calculating the respiratory exchange ratio (RER), and reporting HR throughout exercise. The K4b² is a lightweight (925-g) unit that is worn on a subject’s torso and that uses telemetry to send data from the exercising subject. Subjects wear a face mask equipped with a turbine flowmeter to allow real-time collection of \( \dot{V}O_2 \) data. Previous research comparing the K4b² with the Douglas bag method over a range of cycling exercise intensities, from rest to 250 W, showed no significant differences between K4b² and Douglas bag \( \dot{V}O_2 \) values; these data suggested that the K4b² portable metabolic system was acceptable for measuring \( \dot{V}O_2 \) values over this range of exercise intensity. The K4b² was

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>( \bar{x} )</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>82.4</td>
<td>5.4</td>
<td>73–93</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>25.9</td>
<td>5.1</td>
<td>19.1–36.8</td>
</tr>
<tr>
<td>Mini-Mental State Examination score(^a)</td>
<td>26.9</td>
<td>2.1</td>
<td>24–30</td>
</tr>
<tr>
<td>Time since entry into long-term care residence</td>
<td>2.2 y</td>
<td>4.6 y</td>
<td>1 mo–20 y</td>
</tr>
<tr>
<td>Assistive device used (no. of subjects)</td>
<td>None</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cane</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rolling walker</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard walker</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheelchair (6 self-propelled, 1 electric)</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Chronic health conditions (no. of subjects)</td>
<td>Visual impairment</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cardiovascular disease</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Osteoarthritis</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Memory impairment, gastroesophageal reflux disease</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carcinoma, chronic renal failure, dermatitis, hearing impairment, hypertension, neurogenic bowel and bladder</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Previous fracture</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyperthyroidism, anemia</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Osteoporosis</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyperlipidemia, lumbar spinal stenosis, total hip arthroplasty, pulmonary fibrosis, seizure disorder, Crohn disease</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depression, diabetes</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personality disorder, colitis, vertigo, Paget disease, paraplegia, ploiomyelitis, Parkinson disease</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Total score = 30.
calibrated according to the manufacturer’s instructions prior to each exercise test session and set up for transfer of collected data to a laptop computer via telemetry. Data collection with the K4b2 began at the start of the warm-up period and ended at the completion of the cool-down period.

The rating of perceived exertion (RPE) has been used to monitor exercise intensity for middle-aged adults when the HR response is blunted by HR-controlling medications18 and for older adults (>60 years of age) during walking or treadmill or cycle ergometer exercise.19–24 During maximal graded cycle ergometer exercise, older women (>70 years of age) were able to quantify their sense of effort very well by using the RPE (RPE-HR relationship, r=.95).24 In another study,23 the RPE was accurately used by a group of women (>70 years of age) to regulate exercise intensity during a training program.

### Submaximal Exercise Protocol

The exercise protocol for this study was modified from the Young Men’s Christian Association (YMCA) protocol.25 Each of the 3 constant workload levels was lengthened from 3 to 4 minutes to allow more time for the older adults in the present study to reach steady-state HR and VO2 levels.26 Warm-up and cool-down phases remained the same as those in the YMCA protocol.25 Subjects completed a practice exercise session on the NuStep prior to 2 exercise test sessions. During the practice session, subjects wore the K4b2 unit and the Polar Vantage NV chest strap so that they could become familiar with the equipment, exercise protocol, and exercise motion and so that we could determine the workloads to be used for the 2 standardized exercise test sessions. Subjects were seated comfortably on the NuStep with a 5-degree knee bend at maximal leg extension and a 5-degree elbow bend at maximal arm extension. The seat position and arm length were noted so that we could standardize subject positioning during the exercise test sessions. Resting HR and BP values were obtained, and age-predicted maximal HR (HRmax) was calculated with the equation 208−(0.7×age).27 A metronome provided audible cues for a rate of 60 arm and leg push-pull cycles per minute during exercise. Subjects also watched the stepping rate displayed on the NuStep LCD panel so that they could monitor and adjust their tempo of push-pull cycles.

During the practice session, subjects completed 2-minute bouts of exercise on the NuStep at progressively higher workloads (range=1–8) to determine their HR responses and RPE scores at each workload. At the highest workload attained, subjects completed 4 minutes of exercise without exceeding 75% of the age-predicted HRmax to confirm their ability to complete this level of exercise. At the end of the practice session, a workload was determined for each of the three 4-minute stages of exercise in preparation for the 2 exercise test sessions. The workload for stage 1 (workload 1) was the highest workload given an RPE of 3 by the subject. The stage 3 workload (workload 3) was the highest workload for which the subject could complete 4 minutes of exercise. The stage 2 workload (workload 2) was selected to represent a workload halfway between those selected for stages 1 and 3. For each subject, age-predicted HRmax calculations, seat position and arm length, and workload for each of the 3 stages of exercise from the practice session were transferred to day 1 and day 2 data collection sheets to standardize the exercise protocol and subject positioning for testing. Within 10 days of the practice session, subjects completed 2 standardized exercise test sessions at the selected workloads.

![Figure 1.](image_url)

Subject performing the submaximal exercise protocol on the NuStep TRS 4000 Recumbent Cross Trainer.

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At the onset of the warm-up period, the K4b² unit was turned on for continuous data collection throughout the exercise protocol and the cool-down period for each subject. Data from the NuStep, including displayed HR, MET values, and watts, and subjects’ reported RPE scores were manually recorded on a data collection sheet during testing. In the third and fourth minutes of an exercise stage, NuStep MET values and watts were recorded every 6 seconds. During testing, subjects provided an RPE score at the end of the second minute in each 4-minute exercise stage. Heart rate, as displayed on the NuStep LCD panel, was recorded for each minute of warm-up, exercise, and cool-down periods. For the cool-down period, subjects were instructed to exercise slowly for 5 minutes at workload 1. If the HR was greater than 5 beats above the resting HR after 5 minutes, then the cool-down period was extended. Blood pressure was recorded after the completion of the cool-down period for safety and as a measure of recovery. The same exercise protocol, equipment, and individualized positioning were used for subjects during day 2 testing.

Data Analysis

Descriptive analyses were performed for subjects’ age, body mass index, MMSE score, walking aids, duration of residency, chronic health conditions, and medications. Data reduction was required to generate single data points for K4b² and NuStep MET values and for NuStep watts and HR. The last 30 seconds of breath-by-breath K4b² VO₂ data in the third and fourth minutes of each 4-minute exercise stage were analyzed to produce 2 VO₂ values (milliliters of oxygen per kilogram per minute) per 4-minute exercise stage for each subject. The mean of these 2 VO₂ values was used as the K4b² MET value (1 MET=VO₂/3.5) per exercise stage. The RER values for the subjects were generated by the K4b² software following the completion of testing. The NuStep MET values and watts in the third and fourth minutes of exercise were averaged to produce one MET value and one watt value per 4-minute exercise stage. The HR value for each exercise stage was the average of the HR values in the third and fourth minutes.

To determine whether resting HR, BP, and RER values were different on day 1 and day 2, we performed 3 separate one-way repeated-measures analyses of variance (ANOVA). Six separate one-way repeated-measures ANOVAs were performed to determine whether watts, HR, percentage of HR max (%HR max) achieved, RPE, K4b² MET values, and NuStep MET values by exercise stage were different on day 1 and day 2. To investigate whether watts, HR, %HR max achieved, RPE, K4b² MET values, and NuStep MET values collected on day 1 across the three 4-minute stages of exercise were different from those collected on day 2, we performed 6 separate 2-way repeated-measures ANOVAs. A Tukey post hoc test was used to identify the location of specific differences when the ANOVA omnibus F statistic was significant.

The relationship between group mean MET values from the K4b² and those from the NuStep for each 4-minute exercise stage was determined by use of Pearson r correlation coefficients on day 1 and day 2. The strength of the correlation was characterized as described by Colton: 0 to .25=no relationship, .25 to .50=fair, .50 to .75=moderate to good, and greater than .75=very good to excellent.

The test-retest reliability of NuStep MET values, K4b² MET values, HR, and RPE was determined by use of intraclass correlation coefficients (ICC [2,1]) calculated from the results of the separate 2-way repeated-measures ANOVAs. The ICCs were characterized as described by Vincent, who suggested that ICCs below .80 are of questionable importance for physiological data, whereas...
values of .80 to .89 reflect moderate reliability and values greater than .90 indicate high reliability.

Data were analyzed by use of SPSS-PC (version 15.0). The level of significance was set at $P < .05$ for all statistical tests.

**Results**

**Data Obtained at Rest**

No significant differences were found between day 1 and day 2 resting HR, BP, and RER values (Tab. 2). Data were analyzed by use of SPSS-PC (version 15.0). The level of significance was set at $P < .05$ for all statistical tests.

**Exercise Test Data**

Watts, HR, %HR$_{\text{max}}$, and RPE (Tab. 3) and K4b$^2$ MET values and NuStep MET values (Tab. 4) by exercise stage were not significantly different on day 1 and day 2. Significant differences in exercise responses (Tabs. 3 and 4) were found between the stages of exercise (stage 1 versus stage 2, stage 1 versus stage 3, and stage 2 versus stage 3). These differences in exercise responses with increasing workloads across stages were found for both day 1 and day 2 of testing. Between stages 1 and 2, watts, HR, %HR$_{\text{max}}$, and RPE (Tab. 3) and K4b$^2$ MET values and NuStep MET values (Tab. 4) were different on day 1 ($P < .0001$) and day 2 ($P < .0001$). Furthermore, watts, HR, %HR$_{\text{max}}$, and RPE (Tab. 3) and K4b$^2$ MET values and NuStep MET values (Tab. 4) were different between stages 1 and 3 ($P < .0001$) and between stages 2 and 3 ($P < .0001$).

**Concurrent Validity of NuStep MET Values**

Pearson $r$ correlation coefficients for NuStep and K4b$^2$ MET values at each of the 3 stages of exercise ranged

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Table 3.

Watts, Heart Rate, Percentage of Age-Predicted Maximal Heart Rate (%HR$_{\text{max}}$) Achieved, and Rating of Perceived Exertion at 3 Levels of Submaximal Exercise on 2 Test Occasions (N=18)

<table>
<thead>
<tr>
<th>NuStep Workload, X (Range)$^a$</th>
<th>Stage</th>
<th>Watts (12)</th>
<th>Heart Rate (bpm)</th>
<th>%HR$_{\text{max}}$ Achieved (14)</th>
<th>Rating of Perceived Exertion (15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (1–5)</td>
<td>1</td>
<td>36 (12)</td>
<td>34 (12)</td>
<td>81 (13)</td>
<td>53 (9)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>39 (13)$^b$</td>
<td>39 (14)$^b$</td>
<td>85 (14)$^b$</td>
<td>56 (9)$^b$</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>44 (14)$^c$</td>
<td>44 (15)$^c$</td>
<td>92 (14)$^c$</td>
<td>60 (10)$^c$</td>
</tr>
</tbody>
</table>

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Table 4.

Reliability and Validity of NuStep and K4b$^2$ Values for Metabolic Equivalents of Task (MET Values) at 3 Exercise Stages on Day 1 and Day 2 of Testing (N=18)$^d$

<table>
<thead>
<tr>
<th>NuStep Workload, X (Range)$^b$</th>
<th>Stage</th>
<th>Reliability of:</th>
<th>MET Values on Day:</th>
<th>ICC (2,1) (95% CI)</th>
<th>MET Values on Day:</th>
<th>ICC (2,1) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NuStep</td>
<td>ICC (2,1) (95% CI)</td>
<td>NuStep vs K4b$^2$</td>
<td>ICC (2,1) (95% CI)</td>
<td>NuStep vs K4b$^2$</td>
</tr>
<tr>
<td>3 (1–5)</td>
<td>1</td>
<td>2.20 (0.37)</td>
<td>.89 (.73–.96)</td>
<td>.97 (.91–.99)</td>
<td>.97 (.91–.99)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.36 (0.39)$^c$</td>
<td>.99 (.97–1.00)</td>
<td>.89 (.71–.94)</td>
<td>.89 (.71–.94)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.55 (0.44)$^c$</td>
<td>.99 (.97–1.00)</td>
<td>.92 (.83–.99)</td>
<td>.92 (.83–.99)</td>
<td></td>
</tr>
</tbody>
</table>

---

$^a$ MET values are expressed as group mean (SD). ICC=intraclass correlation coefficient, 95% CI=95% confidence interval of the mean. Pearson $r$ correlation coefficients represent the association between NuStep and K4b$^2$ MET values by exercise stage on day 1 and day 2 of testing.

$^b$ For each workload, SD=1.

$^c$ Significant difference ($P < .05$) between stage 1 and stage 2.

$^d$ Significant difference ($P < .05$) between stage 1 and stage 3 and between stage 2 and stage 3.
from very good to excellent on both
day 1 (r=.97, .89, and .92) and day 2
(r=.86, .85, and .87) (Tab. 4). Bland-
Altman plots were constructed to
provide a visual representation of
systematic bias and variability. In
these plots, subjects' averaged K4b2
and NuStep MET values were plotted
against the difference score for their
K4b2 and NuStep MET values col-
lected during the third and fourth
minutes of an exercise stage. For day
1, there appeared to be a tendency
for the K4b2 to measure higher MET
values compared with the NuStep
(Fig. 2). For day 2, the spread of
scores around the zero point sug-
gested the error was unbiased (Fig.
3). Bland-Altman plots for each exer-
cise stage are shown in Figure 2 for
day 1 and Figure 3 for day 2.

Test-Retest Reliability of Exercise
Responses in Older Adults
The test-retest reliability of HR re-
sponses for the study subjects at
each exercise stage was moderate to
high: ICC (2,1) = .87, .91, and .89.
The data also showed moderate to
high reliability of V̇O₂, or K4b2 MET
values, across the 3 stages of exer-
cise (Tab. 4). In addition, RPE scores
reported by subjects at stages 1, 2,
and 3 of exercise were moderate to
high: ICC (2,1) = .88, .87, and .93,
respectively.

Discussion
The main findings of our study were
that the software-generated NuStep
MET values, or indirect measures of
V̇O₂, were not different from the di-
rectly measured K4b2 MET values
during submaximal exercise in our
sample of frail older adults living in
long-term care centers and that this
group of older adults with multisys-
tem impairments showed reproduc-
ible exercise responses (HR and
K4b2 MET values) during 2 test ses-
sions with a standardized submaxi-
mal 3-stage exercise protocol. These
results are important for physical
therapists and rehabilitation profes-

Figure 2.
Bland-Altman plots of day 1 NuStep and K4b2 metabolic equivalents of task (METs) for
stage 1 (A), stage 2 (B), and stage 3 (C) (N=18). Upper and lower 95% limits of
agreement are shown.
A limitation of the present study was that the complete range of available workloads was not tested. Our subjects exercised up to a mean workload of 5 (range = 3–8) out of 10 workloads. The group mean age-predicted %HR\text{max} achieved at the highest workload tested was 61% (SD = 10%). Only 1 of our 18 subjects was tested at workload 8, possibly because of low levels of aerobic fitness, higher ratings of perceived exertion secondary to a lack of regular aerobic exercise, the cumulative effects of multiple chronic conditions, and the presence in many subjects of chronic cardiovascular conditions (78% of subjects were prescribed β-blockers). Future studies addressing the reliability and validity of exercise responses in older adults at higher NuStep workload levels will need to recruit older subjects with higher functional abilities.

The combined contribution of arms and legs to work output during exercise on the NuStep facilitated exercise participation in our group of older adults with multisystem impairments. Similarly, given that the HR could not be relied on solely to reflect exercise intensity because most subjects were taking β-blockers, the RPE provided a mode for monitoring subjects during exercise and for guiding the choice of workloads.

Figure 3.
Bland-Altman plots of day 2 NuStep and K4b² metabolic equivalents of task (METs) for stage 1 (A), stage 2 (B), and stage 3 (C) (N=18). Upper and lower 95% limits of agreement are shown.
The RPE provided by exercising older adults was shown to be a reliable measure of exercise intensity, with moderate to high ICCs.

Although no randomized clinical trials have examined the therapeutic effects of all-extremity exercise, 2 studies supported the use of combined upper- and lower-limb exercises.\(^{31,32}\) Loudon et al\(^{31}\) compared peak VO\(_2\) values from maximal treadmill and all-extremity ergometer (Pro II Power Trainer\(^{30}\)) tests in women aged 30 to 60 years who were healthy and found that all-extremity exercise was a reliable and valid mode of testing aerobic fitness and a viable alternative to using a treadmill. Hill et al\(^{32}\) demonstrated that the all-extremity Power Trainer safely measured cardiopulmonary fitness in people with movement impairments following a stroke. Finally, Zehr\(^{33}\) suggested that rhythmic movements of the upper and lower limbs on the NuStep during supported sitting elicited neural responses similar to those elicited by walking, and Ferris et al\(^{34}\) reported that rhythmic upper-limb movements resulted in increased lower-limb muscle recruitment, which may benefit people with impairments of the lower or upper limbs or both. These preliminary findings, combined with our results, suggest that all-extremity semirecumbent exercise machines may be a viable exercise option for older adults and other people with health and functional impairments.

**Conclusion**

Software-generated NuStep MET values were shown to be valid compared with K4b\(_2\) direct physiological measurements of VO\(_2\). The exercise responses of frail older adults were reliable across the range of workloads tested in the present study, suggesting that direct physiological assessments are not needed for monitoring subjects when the NuStep is used for exercise testing or training. The present study, therefore, provides preliminary evidence to support the use of the NuStep all-extremity semirecumbent exercise machine for aerobic exercise by older adults who have multiple health conditions and who have difficulty with traditional exercise modalities. The results of this study are important for physical therapists and rehabilitation professionals in hospitals and long-term care centers using these exercise machines to maintain or improve quality of life for frail older adults.

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